

THE EFFECT OF A HYDROFOIL
AT THE STERN OF A
DESTROYER TYPE VESSEL
UPON ITS PERFORMANCE
IN STILL WATER

Elias Venning, Jr.







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by

ELIAS VENNING, JR.

Lieutenant (junior grade), U.S. Navy

B.Sc., U.S. Naval Academy

(1949)

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SUBMITTED

VENNING

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1954

THESIS

V37

Letter on front cover:

THE EFFECT OF A HYDROFOIL/AT THE
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HYDROLOGY

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SUBMITTED IN PARTIAL FULFILLMENT OF

FOR THE DEGREE OF

NAVAL ENGINEER

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

May, 1954

Cambridge, Massachusetts
24 May 1954

Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Sir:

I herewith submit the attached thesis
entitled THE EFFECT OF A HYDROFOIL AT THE
STERN OF A DESTROYER TYPE VESSEL UPON ITS
PERFORMANCE IN STILL WATER in partial ful-
fillment of the requirements for the degree
of Naval Engineer.

Respectfully submitted,

Elias Venning, Jr.

CONFIDENTIAL, 64-14404-107
24 May 1952

Department of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Sir:

I am writing to you regarding the attached thesis
entitled THE EFFECT OF A HORIZONTAL AT THE
END OF A LINEARLY TYPED VERTICAL WALL
THE WALL IS AT THE END OF A LINEAR
element of the fundamental for the design
of naval buildings.
Respectfully,
Eliza Vennard, Jr.

THE EFFECT OF A HYDROFOIL AT THE STERN OF A DESTROYER TYPE VESSEL UPON ITS PERFORMANCE IN STILL WATER, by Elias Venning, Jr. Lieutenant (junior grade), U.S. Navy. Submitted in Partial Fulfillment of the Requirements for the Degree of Naval Engineer, Department of Naval Architecture and Marine Engineering, May 24, 1954.

ABSTRACT

The object of this work was to investigate the effects of a hydrofoil located at the stern of a high-speed surface vessel. Damping out of the first hump in the stern wave train of the vessel appears to be possible by the use of a properly positioned hydrofoil having correct dimensions. Hence, in particular, this thesis was directed toward establishing the effects on total resistance coefficient which resulted from varying hydrofoil chord length, longitudinal position, angle of attack, and depth of submergence.

The vessel tested with stern hydrofoils was a model of a fine-lined, transom-stern, destroyer type ship. To this model were attached hydrofoils whose basic shape corresponded to N.A.C.A. Foil No. 63₂-618. The chord length of this standard shape was varied so as to produce a family of five similar hydrofoils. For each of these hydrofoils the optimum longitudinal position and angle of attack was determined. For the smallest chord length hydrofoil the effect of depth of submergence was evaluated. Finally, with each foil at its optimum position, the effect on the model's total resistance coefficient was established.

As an indication of the results to be achieved with bow hydrofoils on this particular vessel, the final stages of the investigation were devoted to determining the proper position for a bow hydrofoil. The effects produced by locating the hydrofoil at that position were then evaluated.

It was found that for the particular vessel under consideration no reduction in total resistance coefficient by use of stern hydrofoils was possible. Additionally, it further appeared that bow hydrofoils would cause no improvement in total resistance characteristics for this vessel.

THE REPORT IS A SUMMARY OF THE STUDY OF A HYDRAULIC
TYPE TESTS AND INVESTIGATIONS BY A. J. HARRIS, JR.
ELLEN HARRIS, JR. (LAWSON) (JUNIOR) (JUNIOR) (JUNIOR)
SUBMITTED TO THE BOARD OF DIRECTORS OF THE UNIVERSITY
FOR THE DEGREE OF MASTER OF SCIENCE, MAY 14, 1935.
APPROVED AND FORWARDED: MAY 14, 1935.

ABSTRACT

The object of this work was to investigate the effects
of a hydraulic factor of the flow of a liquid through
a pipe. During one of the tests made in the study was
made of the effect of the flow of a liquid through a
pipe of the same diameter as the pipe of the same
material. The results of the tests were as follows:
The flow of a liquid through a pipe of the same
diameter as the pipe of the same material was found to
be the same as the flow of a liquid through a pipe of
the same diameter as the pipe of the same material.
The results of the tests were as follows:
The flow of a liquid through a pipe of the same
diameter as the pipe of the same material was found to
be the same as the flow of a liquid through a pipe of
the same diameter as the pipe of the same material.

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be the same as the flow of a liquid through a pipe of
the same diameter as the pipe of the same material.

As an indication of the progress of the research work
the results of the tests were as follows:
The flow of a liquid through a pipe of the same
diameter as the pipe of the same material was found to
be the same as the flow of a liquid through a pipe of
the same diameter as the pipe of the same material.
The results of the tests were as follows:
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diameter as the pipe of the same material was found to
be the same as the flow of a liquid through a pipe of
the same diameter as the pipe of the same material.

It was found that for the hydraulic factor under
investigation the results of the tests were as follows:
The flow of a liquid through a pipe of the same
diameter as the pipe of the same material was found to
be the same as the flow of a liquid through a pipe of
the same diameter as the pipe of the same material.
The results of the tests were as follows:
The flow of a liquid through a pipe of the same
diameter as the pipe of the same material was found to
be the same as the flow of a liquid through a pipe of
the same diameter as the pipe of the same material.

The presence of stern hydrofoils of varying chord length was consistently deleterious, hence the apparent optimum position and chord length were optimum only in that they caused the least increase in total resistance coefficient. The optimum $(LBP)/(chord\ length)$ ratio was found to be 25.99. The optimum longitudinal position was $1.0115 \times (LBP)$ aft of the forward perpendicular. The optimum $(cut\ away\ angle)/(angle\ of\ attack)$ ratio was $(-) 13$. The optimum depth of submergence was one chord length.

The conclusion drawn from this work is that the application of stern hydrofoils to very fine-lined hull forms will result in no reduction of stern wave making resistance. Additionally, the presence of a bow hydrofoil beneath a bulbous type bow appears to result in no reduction of bow wave making resistance for the hull form that was investigated.

In order to verify the conclusion reached as to the effect of hull form on the results caused by stern hydrofoils, it is recommended that a full-bodied model having the same displacement and wetted surface as that tested in this thesis be built. Then, to this new model apply the same family of stern hydrofoils in order to determine if a beneficial result can be achieved on fuller hull forms.

Thesis Supervisor: Martin A. Abkowitz

Title: Assistant Professor of Naval Architecture

[illegible]

The conclusion drawn from this work is that the application of steam hydrolysis to very low-grade coal forms will result in no reduction of steam costs when compared to the treatment of a low-grade coal. Additionally, the treatment of low-grade coal with steam hydrolysis does not appear to result in no reduction of steam costs when compared to the treatment of a low-grade coal.

[illegible]

Assistant Professor of Social Anthropology

ACKNOWLEDGMENT

It is not possible to give adequate, explicit credit to all those individuals who have directly and indirectly given aid in the development of this thesis. However, the writer is deeply grateful to all of them for their help, and wishes to acknowledge his debt to them.

His greatest debt is to Professor Martin A. Abkowitz, who gave unceasing assistance and encouragement during the conduct of the thesis. In fact, the original idea to employ stern hydrofoils as wave reducing devices was that of Professor Abkowitz. For the timely advice and continuous help given him by this gentleman, he expresses his most sincere thanks.

Special acknowledgment is also due to Mr. N.L. Ficken, Jr. and Mr. J. R. Paulling, Jr., of the staff of the Department of Naval Architecture and Marine Engineering at the Massachusetts Institute of Technology, for their assistance in connection with the experimental and photographic work at the Towing Tank. Their experience greatly assisted the author in the techniques employed to obtain reliable data.

It is not possible to give answers, explicit or implicit, to all these questions and more directly and fully. Given this in the movement of the world, however, the action is nearly isolated and all of them in their own way, and others in combination, are done in them.

[illegible]

Special acknowledgment is also due to Mr. W.L.
Hansen Jr. and Mr. L. C. Phillips, both of the staff
of the Department of Naval Architecture and Marine
Engineering at the Massachusetts Institute of Technology,
for their assistance in connection with the experimental
and photographic work at the towing tank. Their experi-
ence greatly enhanced the value of the technique em-
ployed to obtain reliable data.

Finally, to Mrs. V.A. Manganelli for her untiring secretarial help, the author extends his appreciation.

Cambridge, Mass.
May, 1954

Elias Venning, Jr.

Finally, in the case of the...

...the following...

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NOMENCLATURE

<u>Symbol</u>	<u>Description</u>	<u>Units</u>
R_T	Total Resistance	Lbs.
C_T	Total Resistance Coefficient	---
C_F	Frictional Resistance Coefficient	---
LBP	Length Between Perpendiculars	Ft.
S	Wetted Surface	Ft. ²
V	Speed	Ft./sec. or Knots
ρ	Density of Water	Lb.sec ² /Ft ⁴
ν	Kinematic Viscosity of Water	Ft ² /sec
l	Longitudinal Position of Foil	Ft.
F.A.P.	Forward of After Perpendicular	---
A.A.P.	Aft of After Perpendicular	---
F.F.P.	Forward of Forward Perpendicular	---
A.F.P.	Aft of Forward Perpendicular	---
h	Hydrofoil Depth of Submergence	Inches
α	Hydrofoil Angle of Attack (relative to the horizontal)	Degrees
N.A.C.A.	National Advisory Committee on Aeronautics	---
c	Hydrofoil Chord Length	Inches

TABLE I

Symbol	Description	Units
ρ	Density of liquid	g/cm ³
η	Dynamic viscosity	poise
κ	Thermal conductivity	cal/cm sec deg C
α	Thermal diffusivity	cm ² /sec
β	Thermal expansion coefficient	1/deg C
γ	Surface tension	dyne/cm
δ	Thermal diffusivity of solid	cm ² /sec
ϵ	Dielectric constant	—
μ	Dynamic viscosity of gas	poise
ν	Kinematic viscosity of gas	cm ² /sec
λ	Thermal conductivity of solid	cal/cm sec deg C
σ	Stefan-Boltzmann constant	cal/cm ² sec deg K ⁴
τ	Time	sec
θ	Temperature	deg C
ϕ	Potential function	cal/cm
ψ	Stream function	cm ² /sec
χ	Thermal diffusivity of gas	cm ² /sec
ξ	Thermal diffusivity of liquid	cm ² /sec
ζ	Thermal diffusivity of solid	cm ² /sec
η	Dynamic viscosity of liquid	poise
θ	Temperature	deg C
ϕ	Potential function	cal/cm
ψ	Stream function	cm ² /sec
χ	Thermal diffusivity of gas	cm ² /sec
ξ	Thermal diffusivity of liquid	cm ² /sec
ζ	Thermal diffusivity of solid	cm ² /sec

<u>Symbol</u>	<u>Description</u>	<u>Units</u>
C_L	Coefficient of Lift	----
C_D	Coefficient of Drag	----

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I. INTRODUCTION

Background Theory

1. Resistance Theory.

Any body moving through water will encounter a resistance to its motion. In the case of a body only partially submerged in water, this resistance is made up of three components which are:

1. Frictional resistance
2. Eddy or form resistance.
3. Wave making resistance.

Frictional resistance is a function of the viscosity of the medium, while the wave making resistance is independent of viscosity. Eddy or form resistance was long considered to be independent of viscosity also; however, present-day investigators⁽¹⁾ have established that the form resistance should properly be grouped with the frictional resistance, since they are both dependent on the viscosity of the water. Therefore, they are functions of Reynolds' number, while the wave making resistance is considered to be a function of Froude's

[illegible]

number, $V/\sqrt{gL}$. Now a consideration of the resistance characteristics of ship-shaped bodies in general indicates that at low values of Froude's number $V/\sqrt{gL}$, or speed-length ratio $V/\bar{L}$, the major percentage of a vessel's total resistance is due to friction. However, when the value of the speed-length ratio increases to unity and greater, the wave making resistance shows a sharp increase while the frictional resistance tends to decrease. This increase in wave making resistance at the high speed-length ratios is of considerable significance, for it represents an ever increasing power that must be built into any ship that will be driven at high speeds. Quite obviously, it would be to the designer's advantage if he could achieve a reduction in this high speed wave making resistance by some means which were less costly than the propulsion equipment necessary to achieve the added high speed. With this thought in mind, it then follows that it might be possible to employ some device which would reduce the wave making resistance to a degree significantly greater than the expected increase in the frictional and eddy resistances due to the device.

2. Ship Wave Characteristics

The fact that ships do create waves as they move

[illegible]

5. Spice Wave - 1988

The fact that when we think about the

through water is universally realized, but what is not so widely known is the fact that these waves are really the resultant of two families of waves. The bow and stern of any ship underway are traveling disturbances, and as such they each cause to be formed a wave family which consists of a diverging system and a transverse system. (See Fig. I.) To Lord Kelvin credit is given for a mathematical solution which defines this transverse-diverging wave group in terms of an ideal problem. There are some variations from actuality in the classic Kelvin solution, but these are to be expected since Kelvin considers the disturbance as being due to forces at one single point, whereas for a ship the disturbing forces are spread over the hull. It is to be noted that these two families of waves will change their basic properties of amplitude and wave length as the speed of the ship varies. As the speed increases, the transverse components of each family tend to increase in wave length.

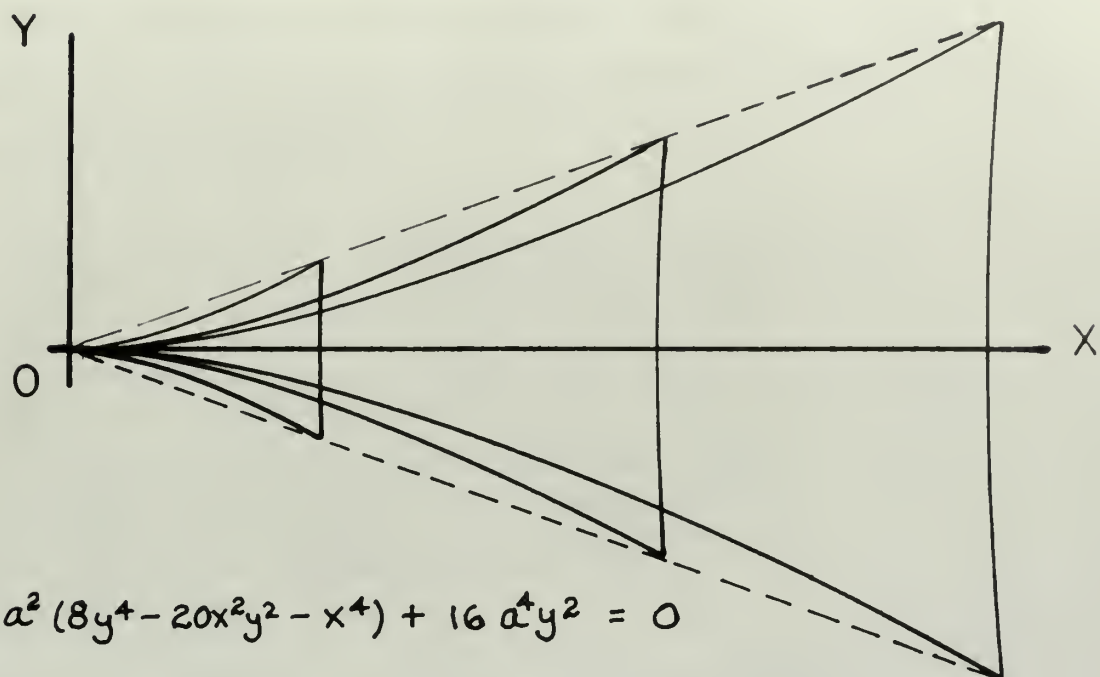
Now in examination of wave making resistance versus speed-length ratio curves, it is customary to find that these curves are characterized by distinct hollows and humps. These hollows and humps are explained by the fact that the bow and stern transverse waves have come into coincidence either in phase so as to result in more

through water in a sufficiently long time, and it is not
 as widely known as the fact that these waves are really
 the vibrations of the medium of water. The two are
 states of the same medium and therefore identical.
 and in fact they are found to be identical. A wave moving
 with constant or a constant speed and a transverse
 vibration (see fig. 1). In fact, a wave moving in
 given for a mathematical relation which follows this
 transverse vibration wave from the time of its birth
 problem. There are some variations from reality in
 the classic Kelvin relation, but there are in the
 motion since Kelvin considers the disturbance as being
 due to a local at the initial point, whereas in a wave
 the disturbance travels the speed of the wave. It is
 to be noted that these two families of waves will always
 with this exception of amplitude and wave length as
 the speed of the wave vector. As the speed increases,
 the transverse component of wave length, and the
 wave length.

Now in examination of wave motion, we find various
 speed-length ratio curves. It is customary to find that
 these curves are characterized by distinct points and
 slopes. These points and slopes are explained by the
 fact that the two wave systems, transverse and longitudinal
 into consideration, which in case of the transverse in water

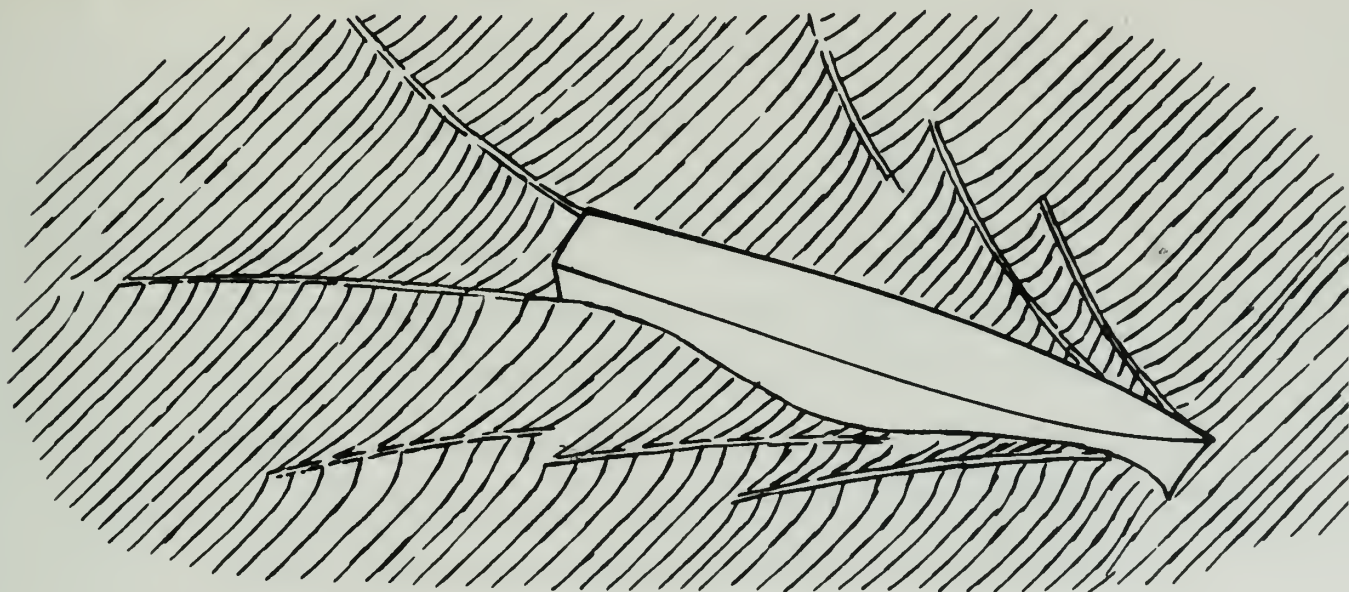
FIGURE I.

KELVIN WAVE GROUP & SHIP WAVE TRAINS



$$(x^2 + y^2)^3 + a^2(8y^4 - 20x^2y^2 - x^4) + 16a^4y^2 = 0$$

CRESTS OF A KELVIN WAVE GROUP CAUSED BY A TRAVELLING DISTURBANCE AT O .



BOW AND STERN WAVE SYSTEMS SHOWING DIVERGENT AND TRANSVERSE CREST GROUPS .

resistance (hence a hump), or out of phase so as to result in less resistance (hence a hollow). Perhaps this phenomena is better explained by quoting the words of Prof. K.S.M. Davidson⁽²⁾:

".... Now the residual resistance is simply the excess of the sum of the aftward-acting components of the normal pressure forces on the fore body over the sum of the forward acting components on the after body. The pressures themselves tend to be high when the surface levels are high, and low when the surface levels are low. Thus the humps and hollows are accounted for, qualitatively, by the effect of the wave train initiated at the bow on the surface levels around the stern." (See Fig. II.)

From the standpoint of reduction of wave making resistance, the essence of what has just been stated is this: if a secondary wave system is imposed upon a primary system so that the two systems are out of phase by 180 degrees, there will be a reduction in the amplitude of the primary system. This reduction can theoretically be a complete reduction to a zero level of disturbance if the amplitude of the secondary system and its other wave characteristics are the same as those of the primary. Assuming that the primary system can be reduced or eliminated by some device, it would appear that a reduction in wave making resistance would result. But now, the problem has been simplified to that of finding a device which is capable of producing a con-

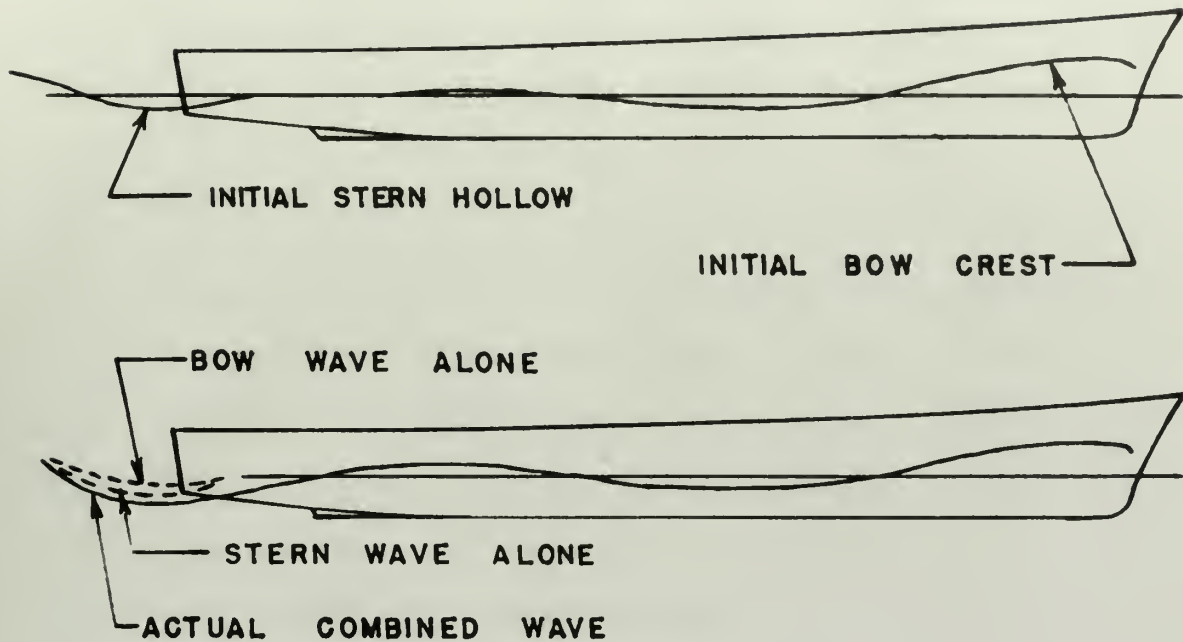
resistance (once a time) or not at all as it is
result in less resistance (once a time), perhaps
this movement is better resisted by pushing the wave
of force, K.A.M., downward (2)

Now the vertical resistance is slightly
the result of the wave of the atmosphere
movement of the signal movement beyond so
the force wave over the wave of the forward
action component in the wave body. The
pressure themselves tend to be high when
the surface level is high, and low when
the surface level is low. Thus the waves
and hollows are accounted for, especially
by the effect of the wave body itself
of the wave on the surface level and
the wave (see fig. 11.)

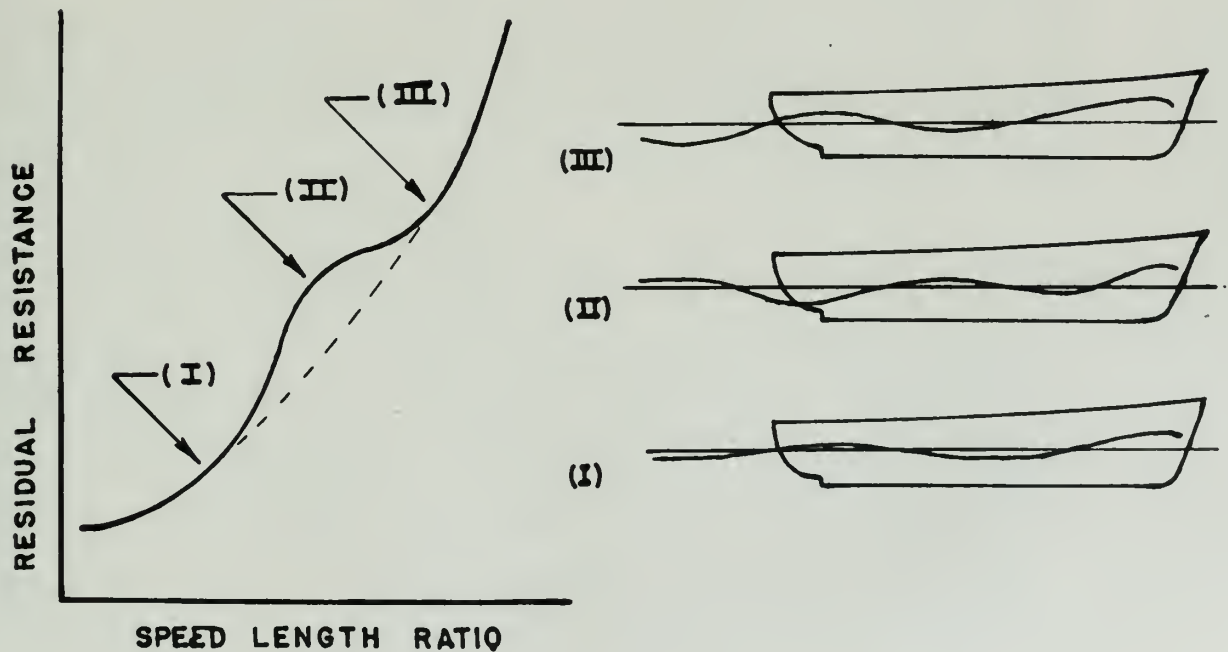
From the standpoint of reduction of wave action
resistance, the essence of what has just been stated
is this: If a secondary wave system is formed upon
a primary system so that the two systems are out of
phase by 180 degrees, there will be a reduction in the
amplitude of the primary system. This condition can
theoretically be a complete reduction to a zero level.
Of course if the amplitude of the secondary system
and the other wave characteristics are the same as those
of the primary. Assuming that the primary system can be
reduced or eliminated by some device, it would appear
that a reduction in wave action resistance would result.
Now, the problem has been simplified to that of
finding a device which is capable of producing a 180-

FIGURE II .

BOW-STERN WAVE INTERFERENCE



IIA. EFFECTS OF BOW & STERN WAVE COINCIDENCE.



II B. CORRELATION BETWEEN WAVE PROFILES & SHAPE OF RESIDUAL RESISTANCE CURVE .

trollable secondary wave disturbance. Such a device might possibly be a hydrofoil, and so let us examine the properties of a hydrofoil.

3. Properties of a Hydrofoil

In addition to the lift and drag characteristics possessed by these underwater wings, or hydrofoils, there is a third characteristic of particular note. Hydrofoils will cause a wave-like disturbance to be set up on the free surface of the water. Keldysch and Lavrentiev⁽³⁾⁽⁴⁾ in 1934 arrived at a two-dimensional treatment of the problem in which they considered the hydrofoil as being a bound vortex. They proposed the following expression which indicated the wave ordinate, y , that exists at a distance x aft of the bound vortex (whose strength is Γ) when the vortex is at submergence h in a free stream velocity of V fps:

$$y = \frac{-2\Gamma}{V} \left[e^{-\frac{1}{V^2} \frac{x^2}{4h}} \right] \sin \frac{gx}{V^2} \quad (1)$$

In practice, this has been found to be a good approximation to the surface for distances of one-quarter wave length or more behind the foil⁽³⁾. The fact that it is an approximation though is easily understood, for when we consider the hydrofoil from a three-dimensional

available secondary wave disturbance. Such a device
 might possibly be a hydrofoil, and so the wave
 the movement of a hydrofoil.

1. HYDROFOILS

In relation to the first two characteristics
 associated with these submerged wings, or hydrofoils,
 there is a third characteristic of particular interest.
 Hydrofoils will cause a wave-like disturbance to be
 set up on the free surface of the water. This
 wave disturbance is called a gravity wave.
 The hydrofoil is said to be a gravity wave.
 They produce the following disturbance when they
 travel the water surface. If the water is at a distance
 x ft. of the wave system (where x is the distance
 the wave is at distance x is a wave system velocity

of V ft/sec)

$$(1) \quad \frac{\partial \eta}{\partial x} = \left[\frac{\frac{\partial \eta}{\partial x}}{V} - \frac{\frac{\partial \eta}{\partial t}}{V} \right] \quad \eta = \frac{\partial \eta}{\partial x} \cdot x + \frac{\partial \eta}{\partial t} \cdot t$$

In relation to the wave system, it is a wave system.
 wave on the surface (or distance of wave system wave
 length is wave length λ). The wave length is
 an approximation though is really understood, for when
 we consider the hydrofoil from a three-dimensional

standpoint we necessarily introduce the effects of trailing vortices. These vortices will produce transverse waves which are noted by the presence of "rooster-tails" in the wake of the foil.

Now, returning to our original proposal to employ some device which would be able to lessen wavenaking resistance, it would appear that a properly positioned hydrofoil adjusted so that it produced high circulation, T , would be an answer to this quest. Accordingly, what has been described before in this Introduction will now serve to explain the reasons behind the investigations and proposals that will next be mentioned.

Chronological Background of M.I.T. Hydrofoil Investigations

This thesis is essentially one more step in a series of investigations at the M.I.T. Ship Model Towing Tank into the use of properly placed hydrofoils as wavenaking reduction devices.⁽⁵⁾

The first investigations were conducted by J.R. Paulling, Jr.⁽⁶⁾ and Henry Kozlowski⁽⁷⁾ in 1952. In the subsequent year of 1953, A.L. Beal and Abraham Zakay⁽⁸⁾ continued Mr. Paulling's investigations. Also in 1953, C.E. Jones and W.H. Brooks⁽⁹⁾ carried out an investigation to determine the nature of the surface waves generated by submerged hydrofoils.

...in the case of the bill.

It should be the desire of this House to determine what has been established before in this Investigation will now serve to establish the future of the investigation and the results of the investigation will be made known.

Approved for Release by NSA on 08-25-2013 pursuant to E.O. 13526

INVESTIGATION OF THE U.S. AIR FORCE'S
RESEARCH AND DEVELOPMENT PROGRAMS
IN THE AREA OF AIRCRAFT
DESIGN AND CONSTRUCTION

Messrs. Paulling, Beal, and Zakay have shown that a reduction in wavemaking resistance can be achieved by the use of bow hydrofoils of proper design. Mr. Kozlowski in the final stages of his investigative work obtained results that indicated that horizontally placed stern hydrofoils also could bring about a reduction in wave making resistance.

Intentions of This Investigation

This investigation serves to continue Mr. Kozlowski's work with a more detailed analysis of stern hydrofoils. In particular it was decided that the effects of varying the hydrofoil chord length, angle of attack, depth of submergence and fore-and-aft position would be investigated. In order to shorten the testing schedule so that it could be completed in the available time, it was further decided to investigate the effects of the stern hydrofoil at only two ship-speed ranges, namely, 15 knots and 32 knots. These, of course, were the most significant speeds since they represented the cruising and full power speeds of the actual vessel. If a significant reduction in wave making resistance could be achieved in either or both of these ranges, then there would be justification for consideration of the hydrofoil's effect over the entire speed range. With these thoughts in mind, let us

next consider the equipment that was employed in this investigation.

Description of Equipment

1. Ship Model

The selection of the model to be tested required that careful attention be paid to the limitations on model size brought about by the physical dimensions of the M.I.T. Towing Tank, which was to be the location of testing. Mr. Kozlowski in his work had employed a model of a destroyer type vessel whose length was 5.5 feet. In order to reach the designed 1.82 speed-length ratio of the ship, he found it necessary to drive the model to a speed of 4.26 knots. At this high speed he found that the model was very liable to yaw, and that the runs were of such short duration that many runs had to be repeated in order to be certain of the reliability of the readings.

It was therefore clear that a smaller model than that employed by Mr. Kozlowski was needed. Accordingly, arrangements were made with the David W. Taylor Model Basin for the loan of a suitable model. The model received was that of a fine lined, transom-stern, anti-submarine-warfare type vessel. The designed speed

length ratio of the ship was 1.403 which necessitated driving the 4.333 ft. model to only a speed of 2.920 knots when considering the 32 knot speed range of the full size ship. Full details of this model will be found in Appendix A, and a photograph of it may be seen in Figure III.

2. Model Towing Bracket. (see Fig. IV.)

Upon receipt of the 4.333 foot model from the David Taylor Model Basin, it was clear that the very light weight of the model (7.63 pounds) and its very narrow beam (0.446') would possibly cause stability problems during towing. The conventional towing bracket used at the M.I.T. Towing Tank is designed for models of 25 pounds or more in weight. These heavier models make it quite acceptable to add a horizontal, hollow, aluminum bar at the upper ends of the towing arms, in which is carried a spring loaded mechanism for adjusting towing cable tension to five pounds. However, for this lighter 7.63 pound model it was indicated that a special lightweight towing bracket was necessary so as to guard against possible capsizing of the model.

The possibility of capsizing was due to the high weight of the tension adjusting rod, hence elimination of this danger called for elimination of the tension

[illegible]

FIGURE III
Model DTMB-DD 332



Note permanently installed level on forecastle, and plastic covering over open portions of hull.



FIGURE IV
Details of Balsa Towing Bracket



Note the heavy tension setting bar in the foreground. P.I.T. Towing Tank bracket is shown in the background. Contrast this with the balsa bracket in the middle which has a lower center of gravity.

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adjusting device. It was with some misgivings that the decision to eliminate this device was made. The applied towing force for any given run must be corrected for the frictional resistance introduced by the dynamometer system. In order to evaluate the magnitude of this frictional resistance it is necessary to maintain a constant static tension in the towing cable. Of course, this tension could be varied, but it is the practice to maintain it at five pounds. The alternative that had to be accepted was to first set the towing cable tension at five pounds by means of the tension-setting spring-loaded aluminum bar which had been separated from its associated components. When this had been done, a length of very fine bronze wire of low ductility and low elasticity was passed in between the two ends of the towing cable (which were attached to the tension-setting device). This wire was then adjusted in length so that it exactly equalled the distance between the connecting points on the tension-setting device. Thereafter, the five pound pull was transferred to the bronze wire, the tension-setting device was slackened, and then finally removed.

As regards the actual towing arms, they were constructed of $\frac{1}{4}$ -inch sheet balsa wood. They were similar to a T-type stiffener in cross section, and were attached to the model by means of aluminum bearing rings which

[illegible]

fitted over a plexiglass shaft. This shaft in turn was rigidly attached to the model by aluminum angle pieces. As can be inferred from this description, every effort was made to keep the towing bracket as light as possible, but still of adequate strength. Details of this arrangement may be seen most clearly in Figure IV.

3. Hydrofoils. (see Fig. V.)

In the original conception of this thesis it had been intended that before any attempts were made to select a suitable hydrofoil shape there would be a detailed photographic analysis made of the stern wave characteristics of the model. From this analysis it would have been possible to have determined the wave ordinates, y , that were to be cancelled by the secondary wave disturbance created by the submerged hydrofoil. Consideration of the Keldysch-Lavrentiev formula,

$$y = \frac{-2\Gamma}{V} \left[e^{-\frac{1}{V^2} \frac{x^2}{2gh}} \right] \sin \left[\frac{gx}{V^2} \right] \quad (1)$$

will indicate that if we had such wave ordinates, we could substitute their values (with negative algebraic signs) into this formula. Then, for given x values and h values of the hydrofoil, and at a given speed range V , we could determine the necessary value of

After a short time, the water in the tank
 began to rise, and the water level
 was found to be about 10 inches above
 the normal level. The water was found
 to be very pure, and the water level
 was found to be about 10 inches above
 the normal level. The water was found
 to be very pure, and the water level
 was found to be about 10 inches above
 the normal level.

1. Introduction

In the present investigation of the effect of
 the water level on the water level, it has
 been found that the water level is
 about 10 inches above the normal level.
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 10 inches above the normal level. The
 water level is found to be about 10
 inches above the normal level. The
 water level is found to be about 10
 inches above the normal level. The
 water level is found to be about 10
 inches above the normal level.

$$\left(\frac{\partial}{\partial t} \right) \left[\frac{\partial}{\partial x} \left(\frac{\partial}{\partial y} \right) \right] = \frac{\partial}{\partial x} \left(\frac{\partial}{\partial y} \right)$$

will indicate that it is not a simple
 case, and the water level is found to
 be about 10 inches above the normal
 level. The water level is found to be
 about 10 inches above the normal level.
 The water level is found to be about
 10 inches above the normal level. The
 water level is found to be about 10
 inches above the normal level.

FIGURE V
Family of N.A.C.A. 62₃-618 Hydrofoils



As used in this investigation. Note the unfinished, as-cut,
1.0 inch hydrofoil in the foreground.



circulation, Γ , that would have to exist to satisfy the equation.

Now for an air foil, or hydrofoil, the circulation around the foil is defined by: ⁽¹⁰⁾

$$\Gamma = \frac{1}{2} C_L U_o c \quad (2)$$

This expression indicates that for a given approach velocity, u_o , the produced circulation, Γ , is directly proportional to the coefficient of lift, C_L , and the foil chord length, c .

If circulation was the only characteristic affected by changes in the coefficient of lift and the chord length, the problem would be much simplified. However it must be realized that there are two additional foil characteristics that will be affected by any change in C_L or c . When C_L is increased, there is generally an increase in the coefficient of drag, C_D , of the foil. This infers an increased form resistance. Additionally, as the chord of the foil is increased, the wetted surface of the hydrofoil is increased, and this infers an increased frictional resistance. Hence discrimination must be exercised in a selection of C_L and c that are to produce the required circulation.

Now if it had been possible to photographically determine the wave ordinates, an analysis could have

circulation, T , that would have no effect on velocity the
 equation

Now for the case of a liquid, the circulation
 around the foil is constant and

$$(2) \quad \Gamma = \frac{1}{2} U \Delta C_L$$

This equation indicates that for a given approach
 velocity, U , the proposed circulation, Γ , is directly
 proportional to the coefficient of lift, C_L , for the
 foil chord length, Δ .

If circulation was the only characteristic
 affected by changes in the coefficient of lift and the
 chord length, the analysis would be very simplified.
 However, it must be realized that there are two additional
 foil characteristics that will be affected by any change
 in C_L or Δ . When C_L is increased, there is usually an
 increase in the coefficient of drag, C_D , of the foil.
 This implies an increased form resistance. Additionally,
 as the chord of the foil is increased, the wetted sur-
 face of the foil is increased, and this tends to
 increase frictional resistance. Hence, drag resistance
 goes on to increase in a relation to C_L and Δ that are
 as complex as the proposed circulation.
 Thus, it is not possible to theoretically
 determine the true drag force, as analysis could only

been made to have determined the optimum values of C_L and c by the use of the Keldysch-Lavrentiev formula. However, other conditions forced this photographic analysis to be omitted. Originally, arrangements had been made with the Sloan Automotive Laboratory machine shop to machine cut the desired hydrofoils during the last part of March 1954. This schedule would have permitted a photographic analysis. Instead, the machine shop found that it was faced with a high priority block of machining work that would be at its peak just when the original schedule had called for the hydrofoils to be cut. Hence, the photographic analysis had to be omitted, for the sake of obtaining the services of the special foil cutting machine.

Lacking a photographic analysis, some other rational methods had to be devised so as to form a basis on which to determine the hydrofoil cross-section, span, chords, and tip shape.

The hydrofoil cross-section selected was based upon a careful consideration of the lift-drag characteristics of the many standard N.A.C.A. sections described in reference (11). What was most wanted in the foils considered was a high lift to drag ratio as the angle of attack of the foil increased. Approximately eight different foils were found to be outstanding in this

[illegible]

...and the ...
...which is ...
...and the ...

[illegible]

property and a selection of any one from among this group was based on very small differences that might easily be considered arbitrary. It is quite possible that the foil shape selected was not the best shape, and that some other shape might have been better, but it is believed that the differences would have been slight. N.A.C.A. section 63₃-618 was therefore selected for this investigation. A list of the other possible foils will be found in Appendix B.

The decision as to the span dimension of the foil was coerced by the need for control over the number of variables that were to be considered. Under the discussion devoted to Intentions of This Investigation it has already been mentioned that hydrofoil chord length, angle of attack, depth of submergence, and fore-and-aft position were the variables under consideration. It was felt that these were the most important variables and that span length should be kept constant at a value equal to that of the model's greatest beam, that is, 0.446 ft.

As regards chord lengths for the hydrofoil, it was the original intention in this investigation that a family of hydrofoils should be tested. This family was to be of the same basic shape (for example, N.A.C.A. 63₃-618) and was to have a constant span of 0.446 ft. However, the chord length was to be varied. Since

property and a collection of very fine specimens of the
 group was taken in very small quantities from the
 early to intermediate stages. It is well known
 that the well known selected was not the best group,
 and that some other group might have been better, but
 it is believed that the differences would have been
 slight. W.A.C. section 15-16-17-18-19-20-21-22-23-24-25-26-27-28-29-30-31-32-33-34-35-36-37-38-39-40-41-42-43-44-45-46-47-48-49-50-51-52-53-54-55-56-57-58-59-60-61-62-63-64-65-66-67-68-69-70-71-72-73-74-75-76-77-78-79-80-81-82-83-84-85-86-87-88-89-90-91-92-93-94-95-96-97-98-99-100-101-102-103-104-105-106-107-108-109-110-111-112-113-114-115-116-117-118-119-120-121-122-123-124-125-126-127-128-129-130-131-132-133-134-135-136-137-138-139-140-141-142-143-144-145-146-147-148-149-150-151-152-153-154-155-156-157-158-159-160-161-162-163-164-165-166-167-168-169-170-171-172-173-174-175-176-177-178-179-180-181-182-183-184-185-186-187-188-189-190-191-192-193-194-195-196-197-198-199-200-201-202-203-204-205-206-207-208-209-210-211-212-213-214-215-216-217-218-219-220-221-222-223-224-225-226-227-228-229-230-231-232-233-234-235-236-237-238-239-240-241-242-243-244-245-246-247-248-249-250-251-252-253-254-255-256-257-258-259-260-261-262-263-264-265-266-267-268-269-270-271-272-273-274-275-276-277-278-279-280-281-282-283-284-285-286-287-288-289-290-291-292-293-294-295-296-297-298-299-300-301-302-303-304-305-306-307-308-309-310-311-312-313-314-315-316-317-318-319-320-321-322-323-324-325-326-327-328-329-330-331-332-333-334-335-336-337-338-339-340-341-342-343-344-345-346-347-348-349-350-351-352-353-354-355-356-357-358-359-360-361-362-363-364-365-366-367-368-369-370-371-372-373-374-375-376-377-378-379-380-381-382-383-384-385-386-387-388-389-390-391-392-393-394-395-396-397-398-399-400-401-402-403-404-405-406-407-408-409-410-411-412-413-414-415-416-417-418-419-420-421-422-423-424-425-426-427-428-429-430-431-432-433-434-435-436-437-438-439-440-441-442-443-444-445-446-447-448-449-450-451-452-453-454-455-456-457-458-459-460-461-462-463-464-465-466-467-468-469-470-471-472-473-474-475-476-477-478-479-480-481-482-483-484-485-486-487-488-489-490-491-492-493-494-495-496-497-498-499-500-501-502-503-504-505-506-507-508-509-510-511-512-513-514-515-516-517-518-519-520-521-522-523-524-525-526-527-528-529-530-531-532-533-534-535-536-537-538-539-540-541-542-543-544-545-546-547-548-549-550-551-552-553-554-555-556-557-558-559-560-561-562-563-564-565-566-567-568-569-570-571-572-573-574-575-576-577-578-579-580-581-582-583-584-585-586-587-588-589-590-591-592-593-594-595-596-597-598-599-600-601-602-603-604-605-606-607-608-609-610-611-612-613-614-615-616-617-618-619-620-621-622-623-624-625-626-627-628-629-630-631-632-633-634-635-636-637-638-639-640-641-642-643-644-645-646-647-648-649-650-651-652-653-654-655-656-657-658-659-660-661-662-663-664-665-666-667-668-669-670-671-672-673-674-675-676-677-678-679-680-681-682-683-684-685-686-687-688-689-690-691-692-693-694-695-696-697-698-699-700-701-702-703-704-705-706-707-708-709-710-711-712-713-714-715-716-717-718-719-720-721-722-723-724-725-726-727-728-729-730-731-732-733-734-735-736-737-738-739-740-741-742-743-744-745-746-747-748-749-750-751-752-753-754-755-756-757-758-759-760-761-762-763-764-765-766-767-768-769-770-771-772-773-774-775-776-777-778-779-780-781-782-783-784-785-786-787-788-789-790-791-792-793-794-795-796-797-798-799-800-801-802-803-804-805-806-807-808-809-810-811-812-813-814-815-816-817-818-819-820-821-822-823-824-825-826-827-828-829-830-831-832-833-834-835-836-837-838-839-840-841-842-843-844-845-846-847-848-849-850-851-852-853-854-855-856-857-858-859-860-861-862-863-864-865-866-867-868-869-870-871-872-873-874-875-876-877-878-879-880-881-882-883-884-885-886-887-888-889-890-891-892-893-894-895-896-897-898-899-900-901-902-903-904-905-906-907-908-909-910-911-912-913-914-915-916-917-918-919-920-921-922-923-924-925-926-927-928-929-930-931-932-933-934-935-936-937-938-939-940-941-942-943-944-945-946-947-948-949-950-951-952-953-954-955-956-957-958-959-960-961-962-963-964-965-966-967-968-969-970-971-972-973-974-975-976-977-978-979-980-981-982-983-984-985-986-987-988-989-990-991-992-993-994-995-996-997-998-999-1000-1001-1002-1003-1004-1005-1006-1007-1008-1009-1010-1011-1012-1013-1014-1015-1016-1017-1018-1019-1020-1021-1022-1023-1024-1025-1026-1027-1028-1029-1030-1031-1032-1033-1034-1035-1036-1037-1038-1039-1040-1041-1042-1043-1044-1045-1046-1047-1048-1049-1050-1051-1052-1053-1054-1055-1056-1057-1058-1059-1060-1061-1062-1063-1064-1065-1066-1067-1068-1069-1070-1071-1072-1073-1074-1075-1076-1077-1078-1079-1080-1081-1082-1083-1084-1085-1086-1087-1088-1089-1090-1091-1092-1093-1094-1095-1096-1097-1098-1099-1100-1101-1102-1103-1104-1105-1106-1107-1108-1109-1110-1111-1112-1113-1114-1115-1116-1117-1118-1119-1120-1121-1122-1123-1124-1125-1126-1127-1128-1129-1130-1131-1132-1133-1134-1135-1136-1137-1138-1139-1140-1141-1142-1143-1144-1145-1146-1147-1148-1149-1150-1151-1152-1153-1154-1155-1156-1157-1158-1159-1160-1161-1162-1163-1164-1165-1166-1167-1168-1169-1170-1171-1172-1173-1174-1175-1176-1177-1178-1179-1180-1181-1182-1183-1184-1185-1186-1187-1188-1189-1190-1191-1192-1193-1194-1195-1196-1197-1198-1199-1200-1201-1202-1203-1204-1205-1206-1207-1208-1209-1210-1211-1212-1213-1214-1215-1216-1217-1218-1219-1220-1221-1222-1223-1224-1225-1226-1227-1228-1229-1230-1231-1232-1233-1234-1235-1236-1237-1238-1239-1240-1241-1242-1243-1244-1245-1246-1247-1248-1249-1250-1251-1252-1253-1254-1255-1256-1257-1258-1259-1260-1261-1262-1263-1264-1265-1266-1267-1268-1269-1270-1271-1272-1273-1274-1275-1276-1277-1278-1279-1280-1281-1282-1283-1284-1285-1286-1287-1288-1289-1290-1291-1292-1293-1294-1295-1296-1297-1298-1299-1300-1301-1302-1303-1304-1305-1306-1307-1308-1309-1310-1311-1312-1313-1314-1315-1316-1317-1318-1319-1320-1321-1322-1323-1324-1325-1326-1327-1328-1329-1330-1331-1332-1333-1334-1335-1336-1337-1338-1339-1340-1341-1342-1343-1344-1345-1346-1347-1348-1349-1350-1351-1352-1353-1354-1355-1356-1357-1358-1359-1360-1361-1362-1363-1364-1365-1366-1367-1368-1369-1370-1371-1372-1373-1374-1375-1376-1377-1378-1379-1380-1381-1382-1383-1384-1385-1386-1387-1388-1389-1390-1391-1392-1393-1394-1395-1396-1397-1398-1399-1400-1401-1402-1403-1404-1405-1406-1407-1408-1409-1410-1411-1412-1413-1414-1415-1416-1417-1418-1419-1420-1421-1422-1423-1424-1425-1426-1427-1428-1429-1430-1431-1432-1433-1434-1435-1436-1437-1438-1439-1440-1441-1442-1443-1444-1445-1446-1447-1448-1449-1450-1451-1452-1453-1454-1455-1456-1457-1458-1459-1460-1461-1462-1463-1464-1465-1466-1467-1468-1469-1470-1471-1472-1473-1474-1475-1476-1477-1478-1479-1480-1481-1482-1483-1484-1485-1486-1487-1488-1489-1490-1491-1492-1493-1494-1495-1496-1497-1498-1499-1500-1501-1502-1503-1504-1505-1506-1507-1508-1509-1510-1511-1512-1513-1514-1515-1516-1517-1518-1519-1520-1521-1522-1523-1524-1525-1526-1527-1528-1529-1530-1531-1532-1533-1534-1535-1536-1537-1538-1539-1540-1541-1542-1543-1544-1545-1546-1547-1548-1549-1550-1551-1552-1553-1554-1555-1556-1557-1558-1559-1560-1561-1562-1563-1564-1565-1566-1567-1568-1569-1570-1571-1572-1573-1574-1575-1576-1577-1578-1579-1580-1581-1582-1583-1584-1585-1586-1587-1588-1589-1590-1591-1592-1593-1594-1595-1596-1597-1598-1599-1600-1601-1602-1603-1604-1605-1606-1607-1608-1609-1610-1611-1612-1613-1614-1615-1616-1617-1618-1619-1620-1621-1622-1623-1624-1625-1626-1627-1628-1629-1630-1631-1632-1633-1634-1635-1636-1637-1638-1639-1640-1641-1642-1643-1644-1645-1646-1647-1648-1649-1650-1651-1652-1653-1654-1655-1656-1657-1658-1659-1660-1661-1662-1663-1664-1665-1666-1667-1668-1669-1670-1671-1672-1673-1674-1675-1676-1677-1678-1679-1680-1681-1682-1683-1684-1685-1686-1687-1688-1689-1690-1691-1692-1693-1694-1695-1696-1697-1698-1699-1700-1701-1702-1703-1704-1705-1706-1707-1708-1709-1710-1711-1712-1713-1714-1715-1716-1717-1718-1719-1720-1721-1722-1723-1724-1725-1726-1727-1728-1729-1730-1731-1732-1733-1734-1735-1736-1737-1738-1739-1740-1741-1742-1743-1744-1745-1746-1747-1748-1749-1750-1751-1752-1753-1754-1755-1756-1757-1758-1759-1760-1761-1762-1763-1764-1765-1766-1767-1768-1769-1770-1771-1772-1773-1774-1775-1776-1777-1778-1779-1780-1781-1782-1783-1784-1785-1786-1787-1788-1789-1790-1791-1792-1793-1794-1795-1796-1797-1798-1799-1800-1801-1802-1803-1804-1805-1806-1807-1808-1809-1810-1811-1812-1813-1814-1815-1816-1817-1818-1819-1820-1821-1822-1823-1824-1825-1826-1827-1828-1829-1830-1831-1832-1833-1834-1835-1836-1837-1838-1839-1840-1841-1842-1843-1844-1845-1846-1847-1848-1849-1850-1851-1852-1853-1854-1855-1856-1857-1858-1859-1860-1861-1862-1863-1864-1865-1866-1867-1868-1869-1870-1871-1872-1873-1874-1875-1876-1877-1878-1879-1880-1881-1882-1883-1884-1885-1886-1887-1888-1889-1890-1891-1892-1893-1894-1895-1896-1897-1898-1899-1900-1901-1902-1903-1904-1905-1906-1907-1908-1909-1910-1911-1912-1913-1914-1915-1916-1917-1918-1919-1920-1921-1922-1923-1924-1925-1926-1927-1928-1929-1930-1931-1932-1933-1934-1935-1936-1937-1938-1939-1940-1941-1942-1943-1944-1945-1946-1947-1948-1949-1950-1951-1952-1953-1954-1955-1956-1957-1958-1959-1960-1961-1962-1963-1964-1965-1966-1967-1968-1969-1970-1971-1972-1973-1974-1975-1976-1977-1978-1979-1980-1981-1982-1983-1984-1985-1986-1987-1988-1989-1990-1991-1992-1993-1994-1995-1996-1997-1998-1999-2000-2001-2002-2003-2004-2005-2006-2007-2008-2009-2010-2011-2012-2013-2014-2015-2016-2017-2018-2019-2020-2021-2022-2023-2024-2025-2026-2027-2028-2029-2030-2031-2032-2033-2034-2035-2036-2037-2038-2039-2040-2041-2042-2043-2044-2045-2046-2047-2048-2049-2050-2051-2052-2053-2054-2055-2056-2057-2058-2059-2060-2061-2062-2063-2064-2065-2066-2067-2068-2069-2070-2071-2072-2073-2074-2075-2076-2077-2078-2079-2080-2081-2082-2083-2084-2085-2086-2087-2088-2089-2090-2091-2092-2093-2094-2095-2096-2097-2098-2099-2100-2101-2102-2103-2104-2105-2106-2107-2108-2109-2110-2111-2112-2113-2114-2115-2116-2117-2118-2119-2120-2121-2122-2123-2124-2125-2126-2127-2128-2129-2130-2131-2132-2133-2134-2135-2136-2137-2138-2139-2140-2141-2142-2143-2144-2145-2146-2147-2148-2149-2150-2151-2152-2153-2154-2155-2156-2157-2158-2159-2160-2161-2162-2163-2164-2165-2166-2167-2168-2169-2170-2171-2172-2173-2174-2175-2176-2177-2178-2179-2180-2181-2182-2183-2184-2185-2186-2187-2188-2189-2190-2191-2192-2193-2194-2195-2196-2197-2198-2199-2200-2201-2202-2203-2204-2205-2206-2207-2208-2209-2210-2211-2212-2213-2214-2215-2216-2217-2218-2219-2220-2221-2222-2223-2224-2225-2226-2227-2228-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Mr. Kozlowski had employed a foil whose L.B.P./chord length ratio was 24 to 1, it was felt that a family of five foils which bracketed this ratio would give reasonable assurance of success. Accordingly, a family of foils having chords of 3 inches, 2.5 inches, 2 inches, 1.5 inches, and 1 inch was decided upon.

Before leaving the discussion of the hydrofoils it should be stated that it was purposely decided to leave the tip edges of the foils blunt and square. It was realized that additional form drag losses, as tip vortices, would result; however, the foils had been machine cut, and hence were as nearly similar as possible. Any tapering of the tips would have been done by hand, and since dissimilarity as well as danger of breakage would result, it was decided not to alter the tips. Additionally, the foils were cut from mahogany, and so a thinning of the tips would have increased the chances of warpage while the foils were submerged. In Appendix C will be found additional details on the N.A.C.A. 63₃-618 shape that was employed.

4. Hydrofoil Support Device and Track (see Fig. VI.)

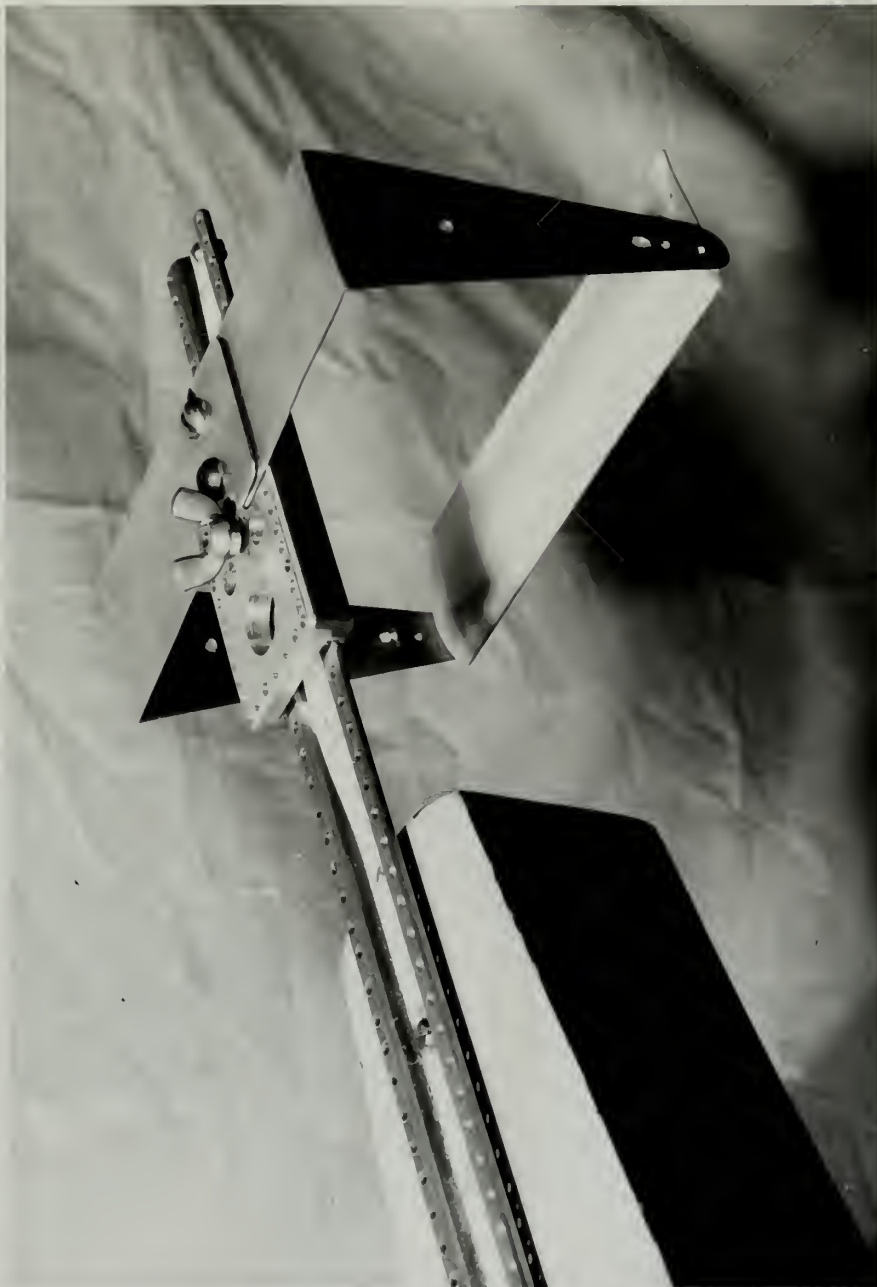
The design of the hydrofoil support device had to meet three requirements. It had to be of minimum weight, had to insure close positioning accuracy, and

Dr. KENNETH C. WILLIS has been awarded a Ph.D. degree from the University of California, San Diego, for his thesis, "The Role of the Hippocampus in the Formation of Spatial Memory." The thesis was supervised by Dr. Robert M. G. Harlow, who was awarded the Nobel Prize in 1960 for his work on the effects of stress on the immune system. Willis' research was conducted in the laboratory of Dr. Harlow, who was a member of the faculty of the University of California, San Diego, from 1955 to 1965. Willis' thesis was published in the journal "Behavioral Science" in 1966.

The design of the Special Agent's uniform was also a result of the fact that the uniform was to be worn by a man in a man's uniform.

FIGURE VI

Details of Stern Hydrofoil Support Device



Showing the 1.5 inch foil set at keel depth.

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most of all, had to be simple in operation. These aims were quite well met in every respect. The support device was of aluminum and lightness was further achieved by liberal use of lightening holes. The positioning track upon which the support device rode was merely a piece of 1 inch wide sail track as used on sail boats. This piece of track was considerably lightened by removing the entire central web of the track with a milling machine. Additionally, the riding lips of the track were lightened by lightening holes.

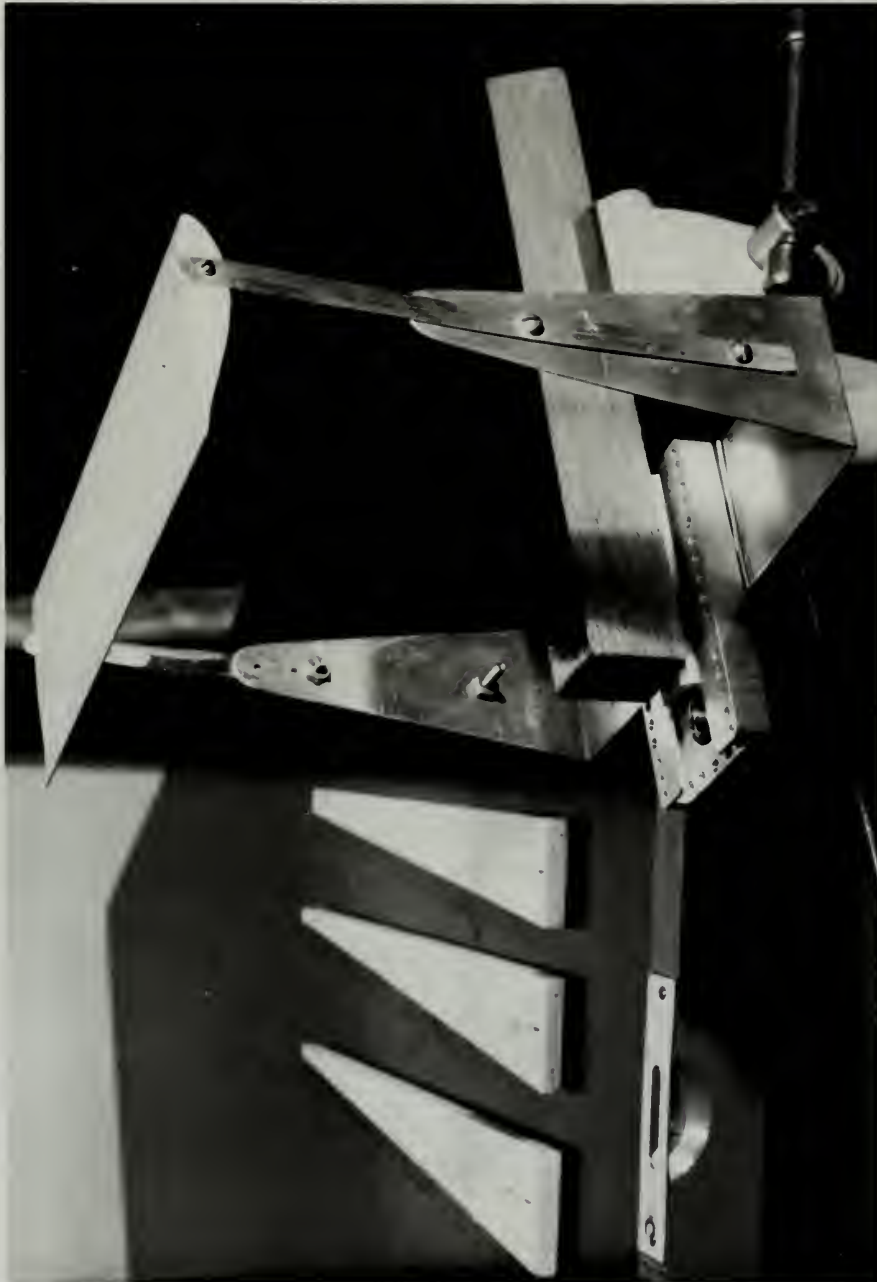
To facilitate the setting of the hydrofoil support device in different positions relative to the After Perpendicular of the model, a plastic strip of 1/16-inch thickness ruled off in 10^{ths} of a foot was inserted between the lips of the positioning track. The rule's A.P. index, was offset three quarters of an inch aft of the A.P. so as to coincide with the index mark on the support device which was three quarters of an inch aft of the support point on the foil. Next, it should be mentioned that the foil support point was at a position on the foil mean line a distance of 25% of the chord aft of the leading edge. (see Appendix C).

5. Devices for Setting Angles of Attack on Foils (see Fig. VII)

A description of the equipment used in this thesis

FIGURE VII

Equipment and Set-up for Setting Angles
of Attack



Note spirit level and declivity boards on table.

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must include those devices used for setting angles of attack on the foils. Perhaps an enumeration of how a given angle of attack is set is the best way to present the description.

A small vise was first secured to a table, and then in the jaws of the vise was set a wooden block to which had been secured a small length of 1-inch sail track. By means of a spirit level, this block was levelled, with the track in an inverted position. Thereafter, the foil support device was attached to the track.

Next, a foil was screwed into position between the arms of the support device. Then, in order to set a given angle of attack, a previously prepared declivity board was set upon the lower face of the foil which was actually in an uppermost position. The spirit level was next set upon this declivity board, and the foil was rotated until the spirit level became level, indicating that the desired angle was set. The one disadvantage of this method was that it necessitated removal of the foil and foil support device from the model if it was desired to check the setting between runs. It was found that accurate and constant fixation of the foil was definitely achieved; however, the author must concede that even more accurate and more simple means of setting angles

most valuable time a person uses for learning is spent
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Next, a toll was removed from the office between
the two of the support devices. Then, in order to
test a given sample of effect, a previously prepared
activity device was used. The device was used to
test which was actually in an emotional condition.
The device level was next set to the device level.
Next, the toll was removed until the device
level became level, indicating that the device level
was set. The new relationship of the device was then
it was indicated removal of the toll and toll support
device from the model is it was desired to check the
relation between them. It was found that support
and constant relation of the toll was necessary.
However, the device was removed from the
model and the device level was set to the device level.

of attack and maintaining them can be devised if
so desired.

II. PROCEDURE

The INTRODUCTION to this thesis has indicated that for a family of five hydrofoils, all of the same basic shape, an investigation was made to determine what effects on total resistance were realized when these foils were mounted aft on a fine-lined transom-stern model. Additionally, it was stated that only model speeds corresponding to 15 knots and 32 knots were to be considered. Further, for each foil an evaluation was to be made of the effects on total resistance resulting from varying the angle of attack, longitudinal position, and depth of submergence.

With the above requirements in mind a procedure was therefore set up which allowed consideration of one variable at a time, while the remaining two variables were held constant. In this manner, the optimum value of one variable, corresponding to certain constant values of the remaining two, was found. Thereafter, this optimum value of the first variable was used as one of the two constants, and then a second variable was considered until an optimum value was found for it. Of course, this procedure was continued for the third variable.

11. DISCUSSION

The EXPERIMENT on this thesis has indicated that for a family of five hypothesis, all of the same value known, an investigation was made to determine what effects the total resistance were realized when these cells were mounted all on a fixed-length random-access model. Additionally, it was stated that only one response corresponding to 15 knots and 25 knots were to be considered. Further, for each cell an evaluation was to be made of the effects on total resistance resulting from varying the angle of attack, longitudinal stability, and depth of immersion.

With the above requirements in mind a procedure was therefore set up which allowed consideration of one variable at a time, while the remaining two variables were held constant. In this manner, the optimum value of one variable, corresponding to certain constant values of the remaining two, was found. Thereafter, this optimum value of the first variable was used as one of the two constants, and then a second variable was considered until an optimum value was found for it. Of course, this procedure was repeated for the third variable.

Now it is readily apparent that this is an iterative solution, and it could have been repeated any number of times desired. In order to carry the first solution through as has been done in this thesis, it was necessary to conduct no less than 337 runs, so it is clear that the number of variables must be limited, or the testing program will become excessively involved.

The model speeds corresponding to 15 and 32 knots on the full size ship were 1.370 and 2.920 knots. Now for any given position of a foil on the model the desired data was the value of the total resistance coefficient at either 1.370 or 2.920 knots. This was most easily found by towing the model at speeds which bracketed those mentioned, and then plotting curves of C_T versus speed-length ratio. The C_T value of the curve at the speed range being considered was then read directly.

Once the value of the total resistance coefficient for a given foil position at either of the speed ranges was found, it next followed that a curve of C_T versus the variable being considered should be plotted. From the shape of this curve it was possible to determine the optimum value of the variable for minimum C_T . This approach was employed in determining both the optimum longitudinal position and the optimum angle of attack for the 1 inch, 1.5 inch and 2 inch hydrofoils.

Now it is readily apparent that this is a desirable condition, and it could have been suggested any number of times desired. In order to carry out this condition through it has been done in this manner, it was necessary to conduct no less than 127 runs, as it is clear that the number of variables must be limited, at the least, to a few. The program will become extensively involved.

The model speed characteristics for 12 and 15 knots in the full size were 1.175 and 1.400 knots. Now let any given position of a ball on the wheel and the first data was the value of the total resistance coefficient at a given speed. The value of C_T was most easily found by using the model at speeds which produced these conditions, and then plotting curves of C_T versus speed-length ratio. The C_T value of the curve at the speed range being considered was then used directly.

Then the value of the total resistance coefficient for a given ball position at each of the speed ranges was found, it was followed that a curve of C_T versus the variable being considered should be obtained. From the shape of this curve it was possible to determine the optimum value of the variable for minimum C_T . This optimum was achieved in determining the optimum longitudinal position and the optimum angle of attack for the 1 inch, 1.5 inch and 2 inch models.

Only in the case of the 1-inch foil was the depth of submergence allowed to vary. References (3) and (9) had indicated that the hydrofoils should not be closer to the free surface of the water than one chord length. Now in order to maintain a realistic approach to possible application of hydrofoils to full size vessels it was made a rigid stipulation that the foils should not be set below the base line of the model. This base line was 1.761 inches below the free surface, and therefore only the 1.5 inch and 1 inch foils were of small enough chord length to permit any movement between limits of one chord length and the base line. Since the allowable downward movement of the 1.5 inch foil was only 0.261 inches, it was decided to keep the depth of submergence constant at 1.761 inches for all foils except the 1 inch foil. In the case of the 1 inch foil the depth of submergence was allowed to vary between the limits of 1 inch and 1.761 inches.

After completion of the optimum attack angle and optimum longitudinal position tests in the 32 knot range on the 1 inch, 1.5 inch and 2 inch stern hydrofoils, it became clear that no reduction in total resistance coefficient was being achieved by the use of the stern hydrofoils. Furthermore, the data that had been collected indicated that the 2.5 inch and 3.0 inch foils would most

There is no more than a few lines of text at the top of the page. The text is very faint and appears to be a list of items, possibly a table of contents or a list of references. The text is arranged in a vertical column and is separated by small gaps. The text is very faint and appears to be a list of items, possibly a table of contents or a list of references. The text is arranged in a vertical column and is separated by small gaps. The text is very faint and appears to be a list of items, possibly a table of contents or a list of references. The text is arranged in a vertical column and is separated by small gaps.

probably produce even worse results. Hence no attempt was made to carry out optimum attack angle and longitudinal position tests on these remaining foils. Instead, on the basis of the curves already plotted, their optimum positions were estimated by extrapolation. They were then set at these positions and tested in the 32 knot range. In the case of the 3 inch foil it was also tested in the 15 knot range. Full details of the series of 14 tests devoted to stern hydrofoil investigation will be found in Appendix D.

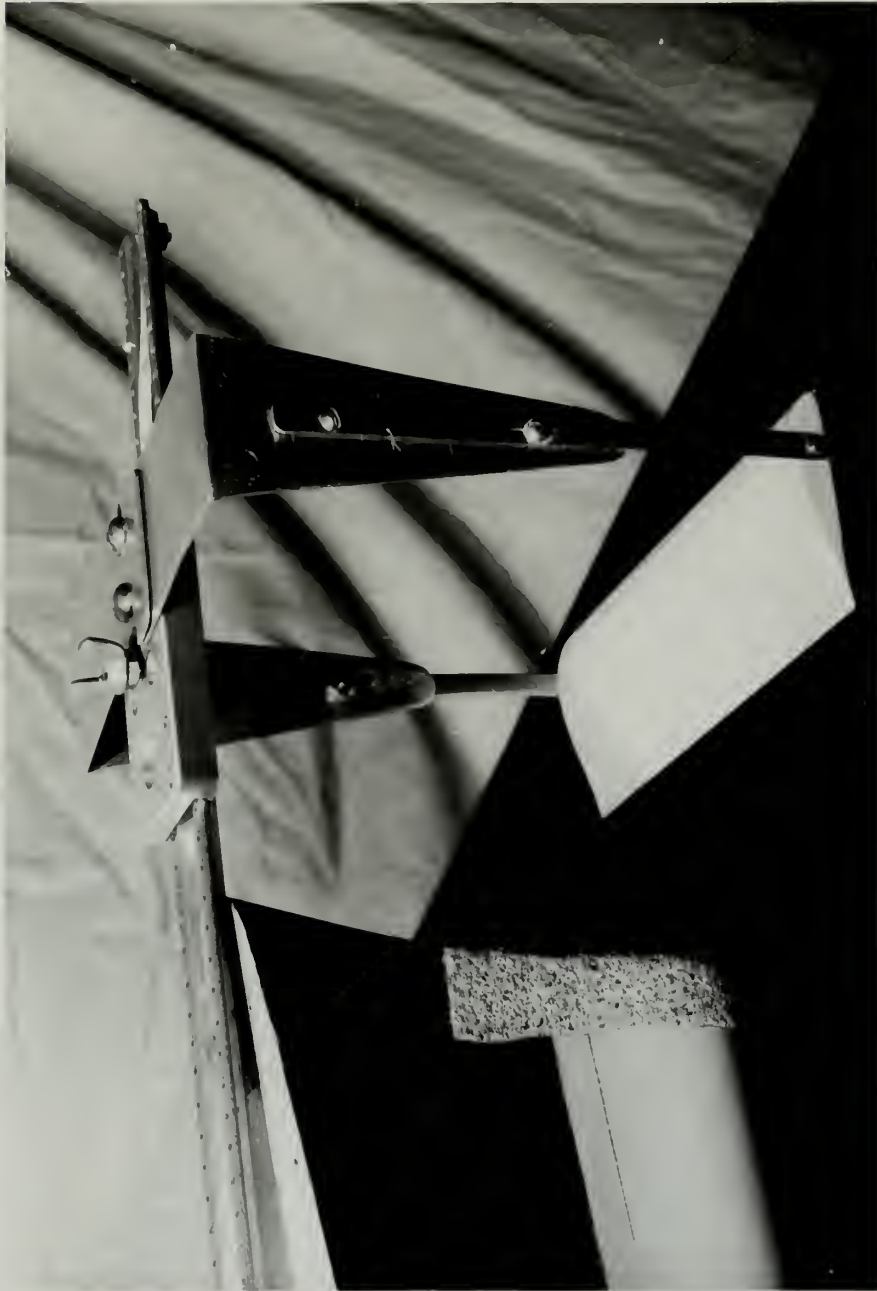
The lack of success achieved with stern hydrofoils on this particular fine-lined model served to arouse curiosity as to whether or not bow hydrofoils might not be more successful. As a final phase of this work, it was therefore decided to determine what results could be achieved by mounting the 2 inch foil on the bow of the model. Slight modifications to the hydrofoil support device in the form of lengthened support arms were necessary. Also, due to the sheer curve of the bow, the support track was mounted somewhat differently. These details will be noted in Figure VIII.

The 2 inch bow hydrofoil was maintained at a constant depth of submergence of 1.761 inches. In the exact same manner as was done in the stern investigation, optimum longitudinal position tests were first carried out followed by optimum attack angle tests.

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FIGURE VIII

Details of Bow Hydrofoil Support Device



Showing the 2.0 inch foil set at keel depth

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III. RESULTS

The results of the various tests conducted on the family of hydrofoils and model DTMB-DD332 are presented in the form of curves. The following listing will serve to describe the purpose of each curve and will indicate the sources of data if it is a curve derived from another curve or curves. These results all pertain to the model only, and in order are:

A. Stern Hydrofoils

1. Figure IX. C_T versus $V/\sqrt{L}$ for the model without and with sandstrips at the beginning of the testing program on 6 March 1954. Also shown on this plot is a re-evaluation of the model's sanded resistance at the 15 and 32 knot ranges. This re-evaluation was made on 2 April 1954, and 10 April 1954, and serves to indicate the increase in total resistance that resulted from severe cracking of the bottom paint on the model.
2. Figure X. C_T versus $V/\sqrt{L}$ for the sanded model with bow and stern hydrofoil support devices attached at the 15 knot range. Also shown is the re-evaluation of the model's total resistance coefficient after subsequent cracking of the bottom paint.

III. RESULTS

The results of the various tests conducted on the family of hyperbolic and model (700-1000) are presented in two sets of curves. The following figures will serve to describe the behavior of the curves and will indicate the manner in which it is a curve derived from another curve or curves. These results all pertain to the model only, but in general:

1. Figure 1

Figure 1, C, versus V/V_0 for the model - shows and also summarizes of the behavior of the family of curves in a graph. Also shown on this plot is a curve evaluation of the model's actual test results at the 12 inch diameter. This curve evaluation was made on 3 April 1954, and is shown to indicate the increase in total resistance that results from severe crushing of the tubes prior to the model.

2. Figure 2

Figure 2, C, versus V/V_0 for the model - shows and also summarizes of the behavior of the family of curves in a graph. Also shown is the re-evaluation of the model's total resistance coefficient after adjustment of the behavior of the tubes.

3. Figure XI. Same as Figure X above, except that this is for the 32 knot range.
4. Figure XII. C_T versus $V/\sqrt{L}$ at 32 knot range, showing intercept curves for the 1 inch hydrofoil at various positions as indicated on the plot.
5. Figure XIII. C_T versus $V/\sqrt{L}$ at 32 knot range, showing intercept curves for the 1.5 inch hydrofoil at various positions as indicated on the plot.
6. Figure XIV. C_T versus $V/\sqrt{L}$ at 32 knot range, showing intercept curves for the 2.0 inch hydrofoil at various positions as indicated on the plot.
7. Figure XV. C_T (at 32 knot range) versus longitudinal position of hydrofoil. This is a family of three curves pertaining to the 1.0, 1.5, and 2.0 inch hydrofoils. They show the effect of varying the hydrofoil's longitudinal position and also show that longitudinal position at which the minimum value of C_T will occur for each foil at the particular attack angle set. Points on these curves are the values of C_T at the 32 knot range as found in Figures XII, XIII, and XIV.
8. Figure XVI. Hydrofoil chord length versus longitudinal position of hydrofoil for minimum C_T at 32 knot range. This curve shows the variation of the optimum longitudinal position for a hydrofoil as we change the chord length. By extrapolation on this curve, a prediction is made as to the optimum longitudinal position for the 2.5 and 3.0 inch hydrofoils at the 32 knot range.
9. Figure XVII. C_T (at 32 knot range) versus hydrofoil angle of attack, with hydrofoils located at their optimum longitudinal positions. This also is a family of three curves pertaining to the 1.0, 1.5, 2.0 inch hydrofoils. These curves show the effect of varying

Figure IV. (at 1000 ft) versus
1.5 inch hydraulic at the 1000 ft

Figure V. (at 1000 ft) versus
1.5 inch hydraulic at the 1000 ft

Figure VI. (at 1000 ft) versus
1.5 inch hydraulic at the 1000 ft

Figure VII. (at 1000 ft) versus
1.5 inch hydraulic at the 1000 ft

Figure VIII. (at 1000 ft) versus
1.5 inch hydraulic at the 1000 ft

Figure IX. (at 1000 ft) versus
1.5 inch hydraulic at the 1000 ft

Figure X. (at 1000 ft) versus
1.5 inch hydraulic at the 1000 ft

the hydrofoil's angle of attack, and also show the angle of attack at which the absolute minimum value of C_T will occur for each foil. As in Figure XV, the points on these curves are the values of C_T at the 32 knot range as found in Figures XII, XIII, and XIV. It is to be noted that each foil was located at its optimum longitudinal position, hence the values of C_T at the optimum angles of attack represent the lowest possible values of C_T that can be achieved at the 32 knot range for the particular foils being considered.

10. Figure XVIII. Hydrofoil chord length versus angle of attack of hydrofoil for minimum C_T at the 32 knot range. This curve shows the variation of the optimum angle of attack for a hydrofoil at the 32 knot range as we change the chord. By extrapolation on this curve, a prediction is made as to the optimum angle of attack for the 2.5 and 3.0 inch hydrofoils at the 32 knot range.
11. Figure XIX. C_T versus $V/\sqrt{L}$ at 32 knot range for the 2.5 and 3.0 inch hydrofoils located at their optimum positions. These optimum positions were determined by extrapolation in Figures XVI and XVIII. Also (in dashed lines) will be found extrapolated curves of C_T versus $V/\sqrt{L}$ for the 1.0, 1.5, and 2.0 inch foils. These curves have one known point, the 32 knot range lowest possible value of C_T . Their slope and shape is based on that indicated in Figures XII, XIII and XIV. They are shown merely for comparison purposes.
12. Figure XX. Chord length versus absolute minimum C_T at the 32 knot range. The points on this curve correspond to the 32 knot range lowest possible values of C_T as indicated in Figure XIX. Corresponding to each chord length, a short dashed line has been drawn in at the value of C_T which was to be expected due to the increased frictional resistance arising from the

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12. Figure 12. Chord length versus absolute minimum Δ of the 12 chord. The points on this curve correspond to the 12 chord length values shown in Figure 11. The curve is a smooth curve and is not a straight line. The curve is a smooth curve and is not a straight line.

added wetted surface of the hydrofoil. (See Appendix E). This is the most important curve in this thesis and will be considered in some detail in the DISCUSSION OF RESULTS.

13. Figure XXI. C_T versus $V/\sqrt{L}$ at the 15 knot range for 1.0 and 3.0 inch hydrofoils located at their optimum positions as found in the 32 knot range tests. This curve is intended to show the range of C_T values to be expected in the high frictional resistance region.
14. Figure XXII. C_T versus $V/\sqrt{L}$ at the 32 knot range for the 1.0 inch hydrofoil at its optimum position. This plot shows the effect on resistance that results from varying the depth of submergence of the 1 inch hydrofoil.

B. Bow Hydrofoils

1. Figure XXIII. C_T versus $V/\sqrt{L}$ at 32 knot range, showing intercept curves for the 2 inch bow hydrofoil, at various positions as indicated on the plot.
2. Figure XXIV. C_T (at 32 knot range) versus longitudinal position of the 2 inch bow hydrofoil. From this curve is obtained the optimum longitudinal position for minimum C_T . Shown on the plot is the predicted optimum longitudinal position. See Appendix F for details of the basis for this prediction.
3. Figure XXV. C_T (at 32 knot range) versus angle of attack for the 2 inch bow hydrofoil located at its optimum longitudinal position. This curve shows the absolute minimum value of C_T that can be achieved with the

should include within the scope of the investigation the following items: (1) The nature of the problem, (2) the objectives of the investigation, (3) the methods to be employed, (4) the results obtained, and (5) the conclusions drawn.

1. Figure 1 - A cross-section of the head of a fish, showing the position of the eye, the ear, and the mouth. The eye is located at the front of the head, the ear is located at the side, and the mouth is located at the bottom.

2. Figure 2 - A cross-section of the head of a fish, showing the position of the eye, the ear, and the mouth. The eye is located at the front of the head, the ear is located at the side, and the mouth is located at the bottom.

References

1. Figure 1 - A cross-section of the head of a fish, showing the position of the eye, the ear, and the mouth. The eye is located at the front of the head, the ear is located at the side, and the mouth is located at the bottom.

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3. Figure 3 - A cross-section of the head of a fish, showing the position of the eye, the ear, and the mouth. The eye is located at the front of the head, the ear is located at the side, and the mouth is located at the bottom.

2 inch bow hydrofoil. A dashed line is also drawn in to show the increase in C_T that was to be expected due to added frictional resistance arising from an increase in wetted surface.

The foregoing represent the graphical presentation of the findings reached in this thesis. In summary, the most significant figures are:

- Figure XX, Lowest C_T to be expected for each stern hydrofoil chord length at 32 knot range.
- Figure XXI, Magnitude of C_T produced by stern hydrofoils in 15 knot range.
- Figure XXII, Effect of variation of depth of submergence of a stern hydrofoil.
- Figure XXIV, Accuracy achieved in predicting optimum location for bow hydrofoil.
- Figure XXV, Lowest C_T to be expected with a 2 inch bow hydrofoil.

I have been thinking of you
 in the light of the fact that
 you are a very good person
 and I am sure you will be
 a great success in the future

The following is a list of the
 of the things which are
 the most important things

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 shows the results of the
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Figure XIV,
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Figure XV,
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FIGURE IX .

C_T VS. $V/\sqrt{L}$ FOR THE MODEL WITH & WITHOUT SAND STRIPS

1. C_T VS. $V/\sqrt{L}$ FOR MODEL WITHOUT SAND STRIPS.

4. C_T VS. $V/\sqrt{L}$ FOR MODEL WITH SAND STRIPS, 6 MARCH 1954.

34. C_T VS. $V/\sqrt{L}$ FOR MODEL WITH SANDSTRIPS AT 32 KT. RANGE, 2 APRIL '54.

38. C_T VS. $V/\sqrt{L}$ FOR MODEL WITH SANDSTRIPS AT 15 KT. RANGE, 10 APRIL '54.

NOTE: THE NUMBER GIVEN EACH CURVE CORRESPONDS TO TABULATED DATA FOR THAT CURVE (IDENTIFIED BY THE SAME NUMBER) AS FOUND IN APPENDIX D .

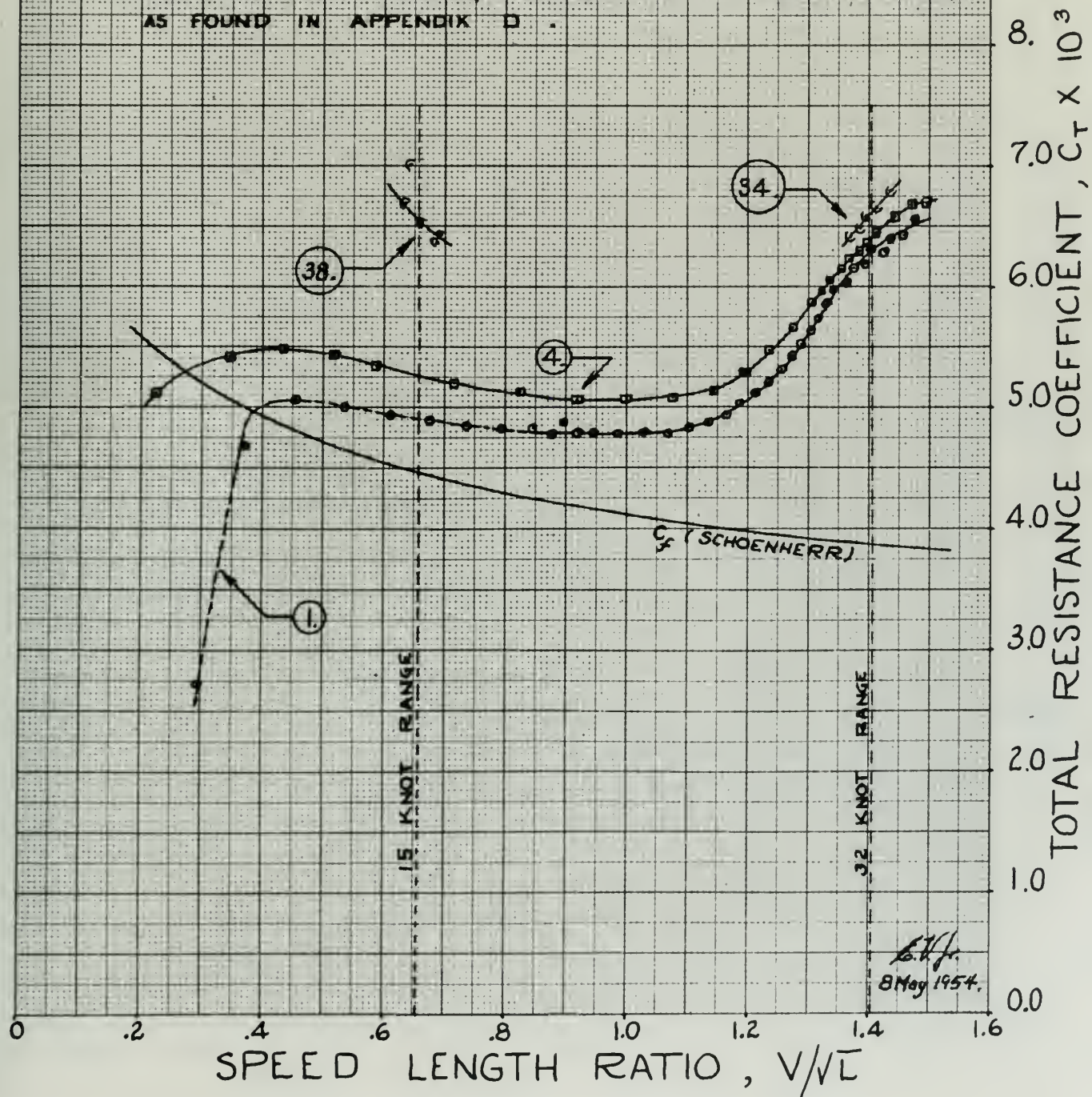




FIGURE X.

C_T VS. $V/\sqrt{L}$ FOR THE SANDED MODEL WITH & WITHOUT STERN HYDROFOIL SUPPORT DEVICE AT THE 15 KT. RANGE

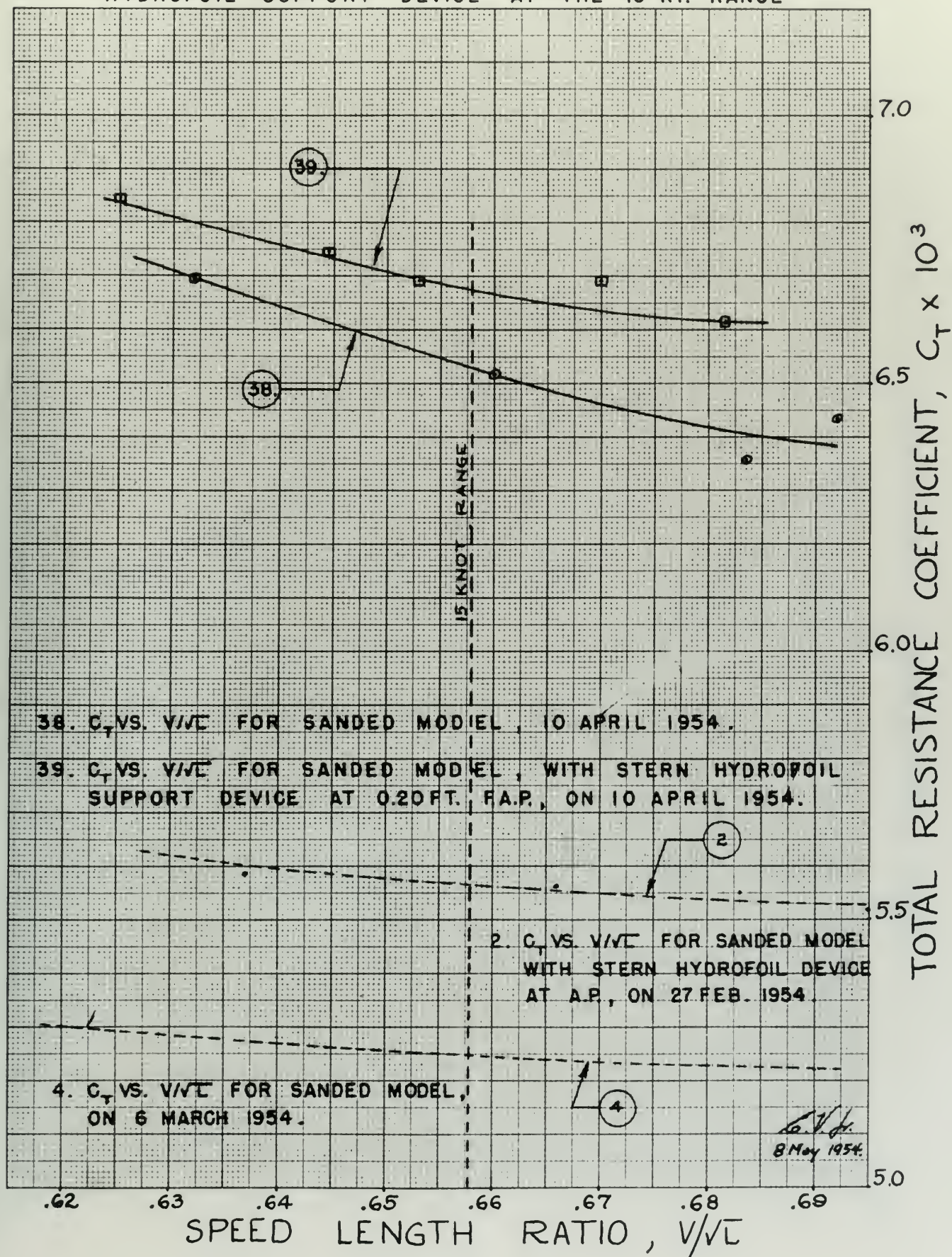




FIGURE XI.

ADDED RESISTANCE CAUSED BY THE HYDROFOIL SUPPORT DEVICES

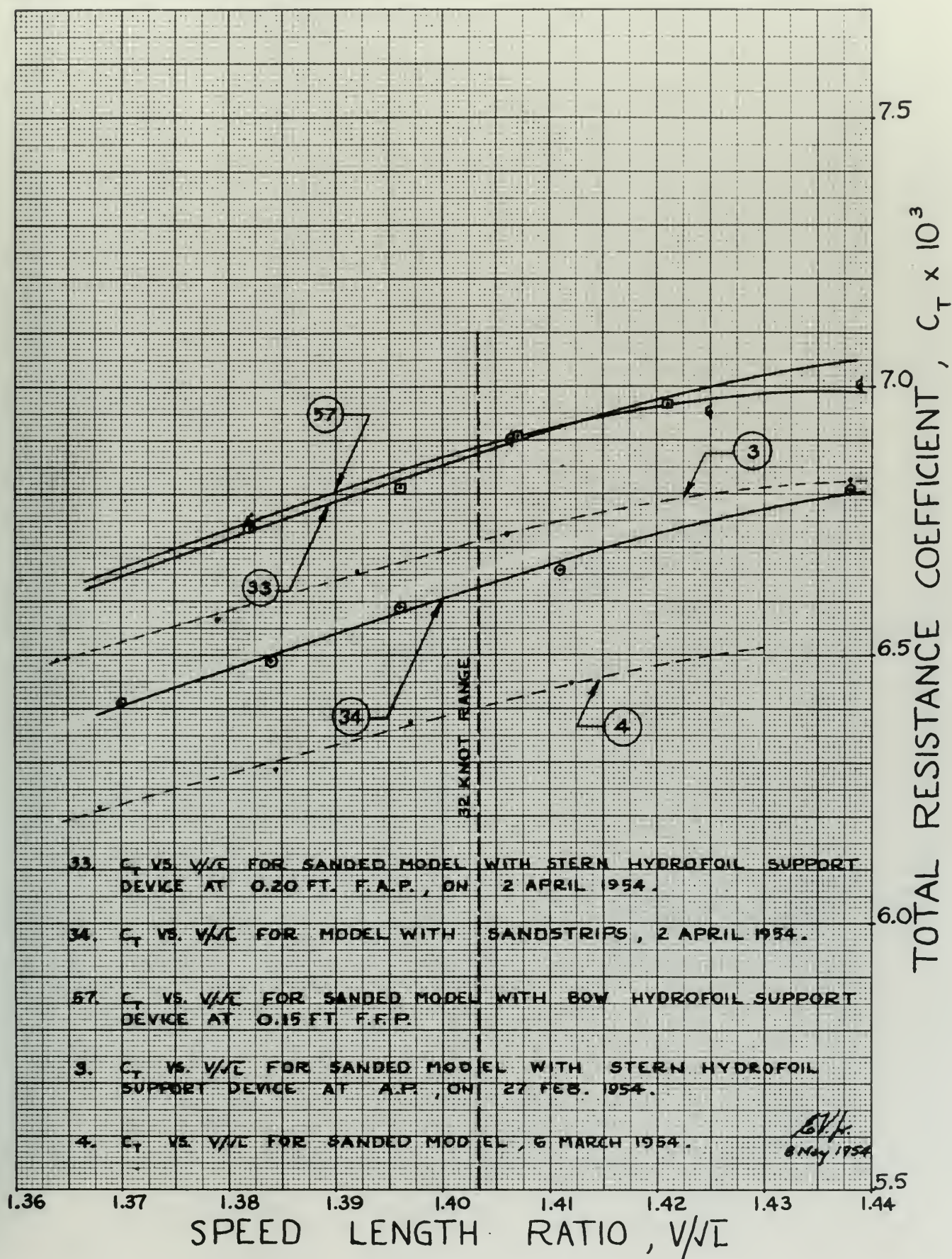
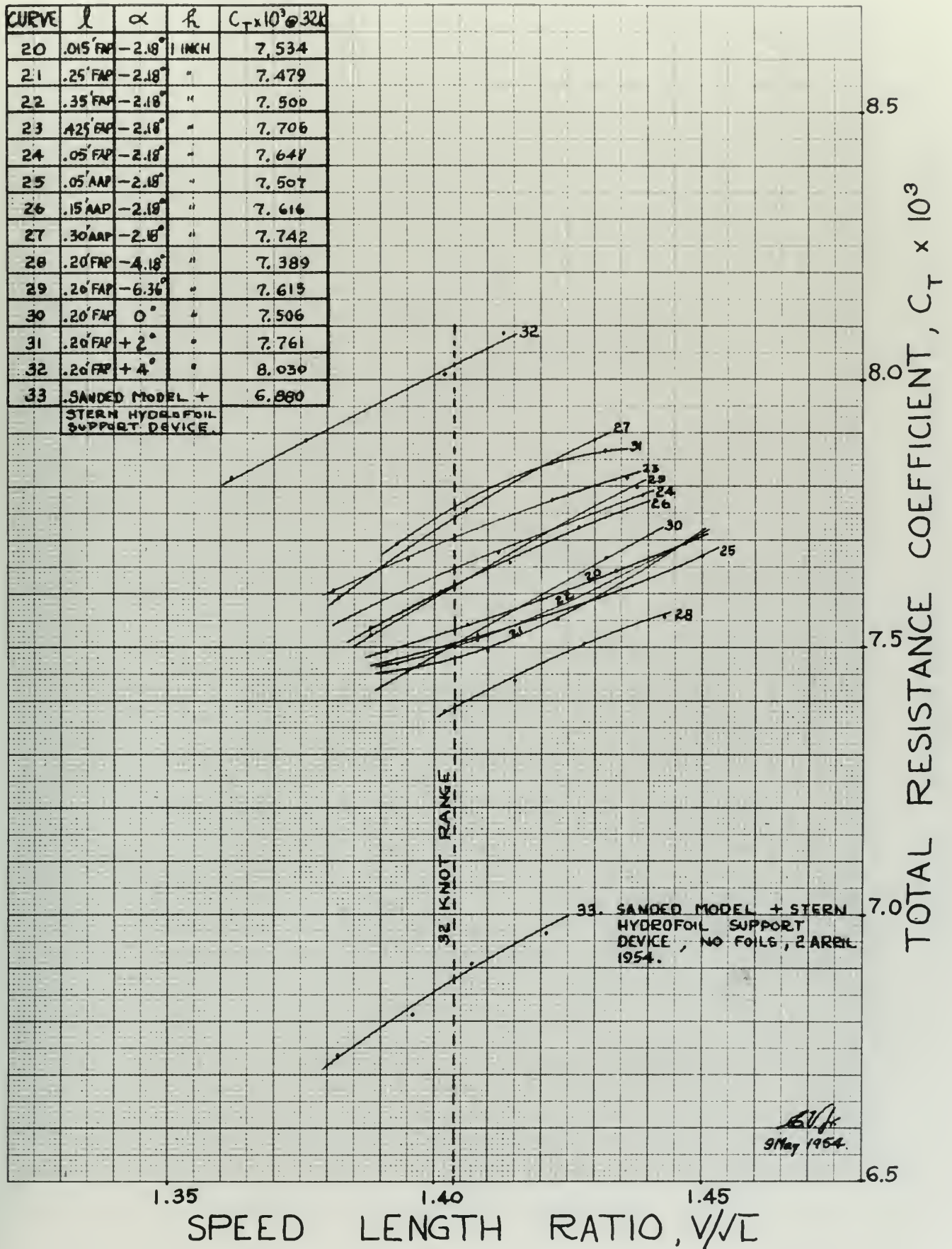




FIGURE XII.

32 KT. RANGE INTERCEPT CURVES FOR 1.0 INCH HYDROFOIL

CURVE	l	α	h	$C_T \times 10^3 @ 32k$
20	.015' FAP	-2.18°	1 INCH	7.534
21	.25' FAP	-2.18°	"	7.479
22	.35' FAP	-2.18°	"	7.500
23	.425' FAP	-2.18°	"	7.706
24	.05' FAP	-2.18°	"	7.648
25	.05' AAP	-2.18°	"	7.507
26	.15' AAP	-2.18°	"	7.616
27	.30' AAP	-2.18°	"	7.742
28	.20' FAP	-4.18°	"	7.389
29	.20' FAP	-6.36°	"	7.615
30	.20' FAP	0°	"	7.506
31	.20' FAP	+2°	"	7.761
32	.20' FAP	+4°	"	8.030
33	SANDWICH MODEL + STERN HYDROFOIL SUPPORT DEVICE.			6.880



9 May 1954.



FIGURE XIII.

32 KT. RANGE INTERCEPT CURVES FOR 1.5 IN. HYDROFOIL

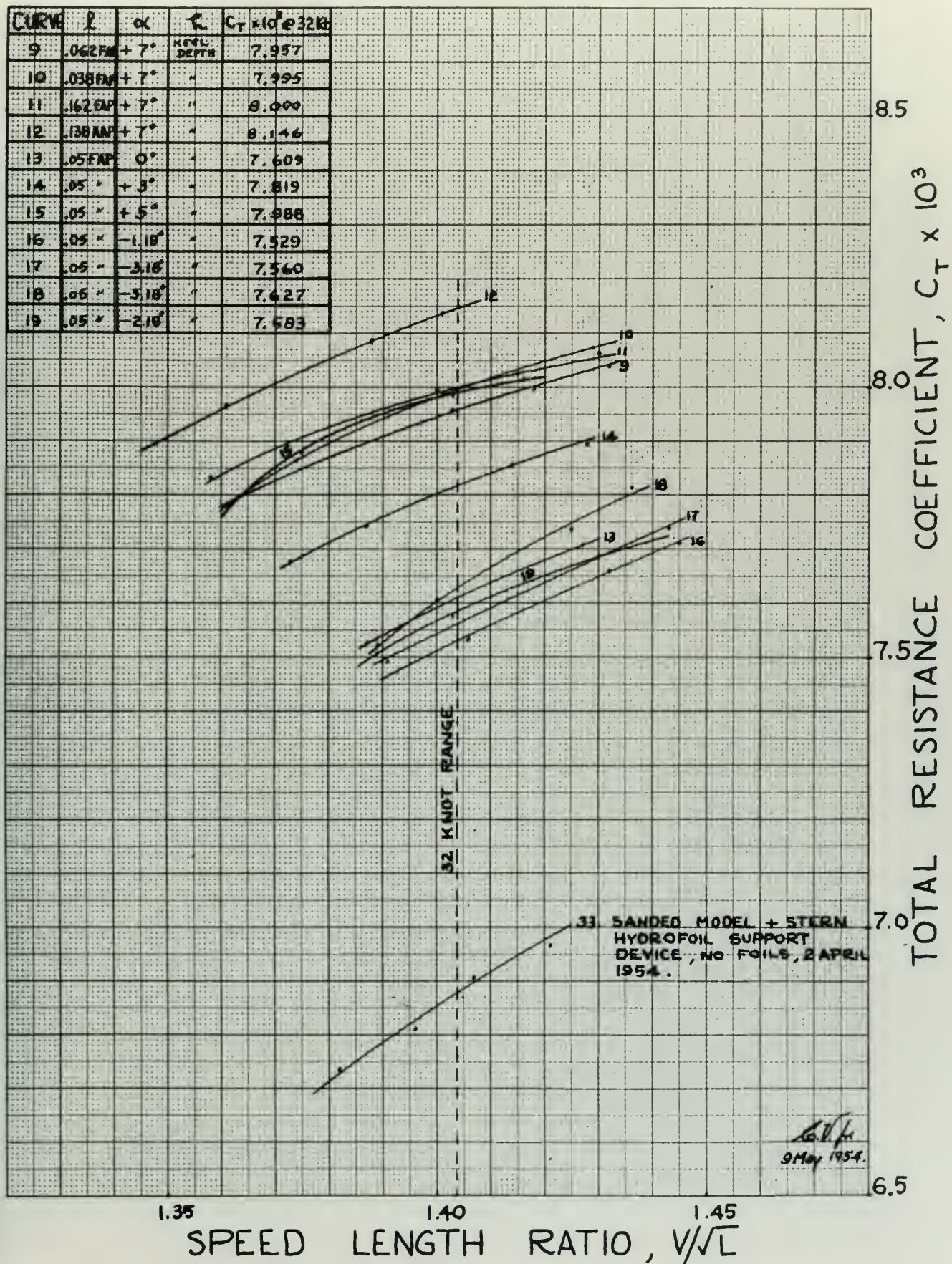
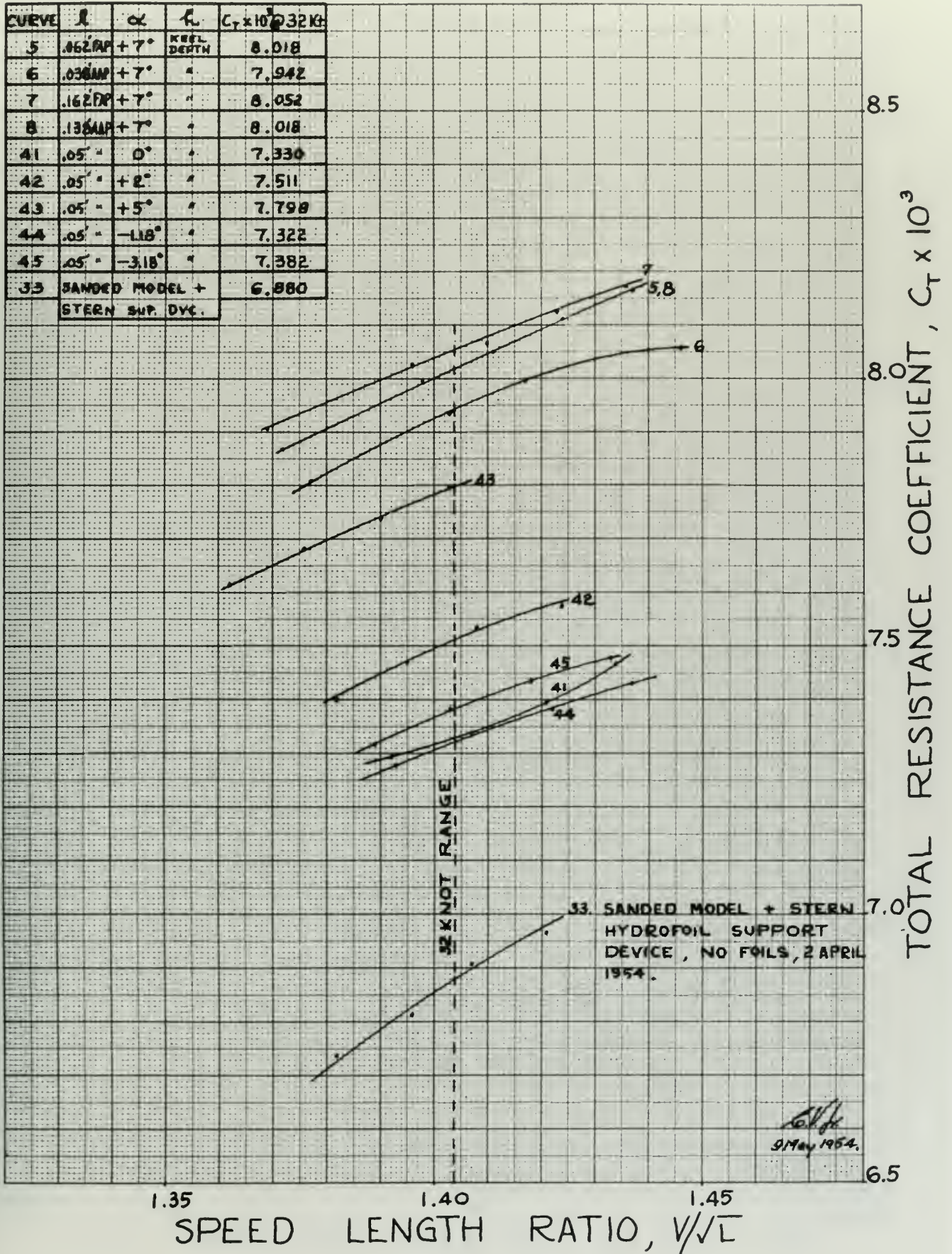




FIGURE XIV .

32 KT. RANGE INTERCEPT CURVES FOR 2.0 IN. HYDROFOIL

CURVE	L	α	L	$C_T \times 10^3$ 32 KT
5	.062 MP	+7°	KEEL DEPTH	8.018
6	.036 MP	+7°	"	7.942
7	.162 MP	+7°	"	8.052
8	.136 MP	+7°	"	8.018
41	.05 "	0°	"	7.330
42	.05 "	+2°	"	7.511
43	.05 "	+5°	"	7.798
44	.05 "	-1.8°	"	7.322
45	.05 "	-3.18°	"	7.382
33	SANDED MODEL + STERN SUP. DYC.			6.880



91 May 1954.



FIGURE XV.

VARIATION OF RESISTANCE WITH CHANGE OF POSITION AT 32KT. RANGE

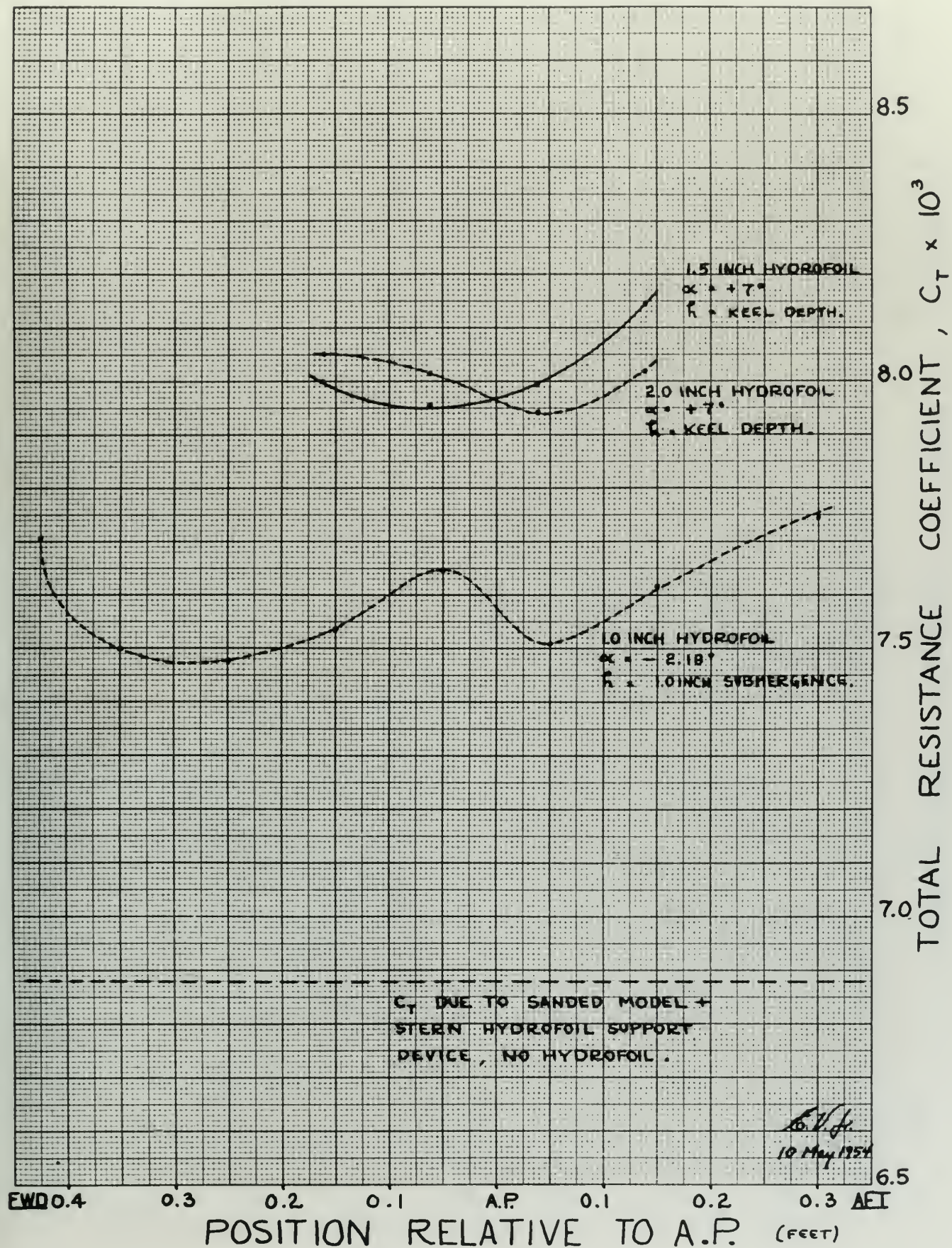


FIGURE XVI.

OPTIMUM POSITION VS. CHORD LENGTH AT 32 KT. RG.

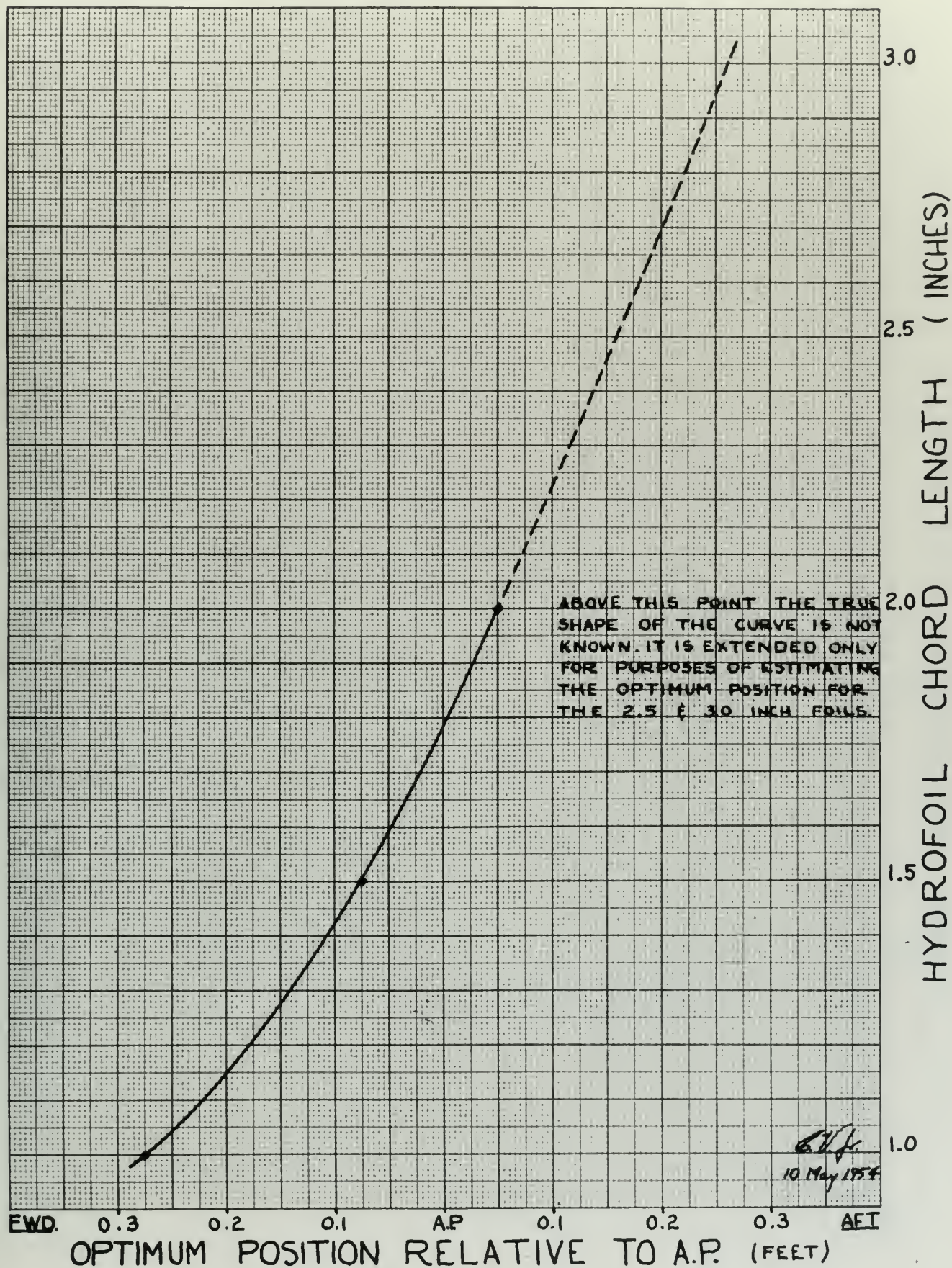




FIGURE XVII

VARIATION OF C_T WITH CHANGE OF ATTACK ANGLE AT 32KT. RG.

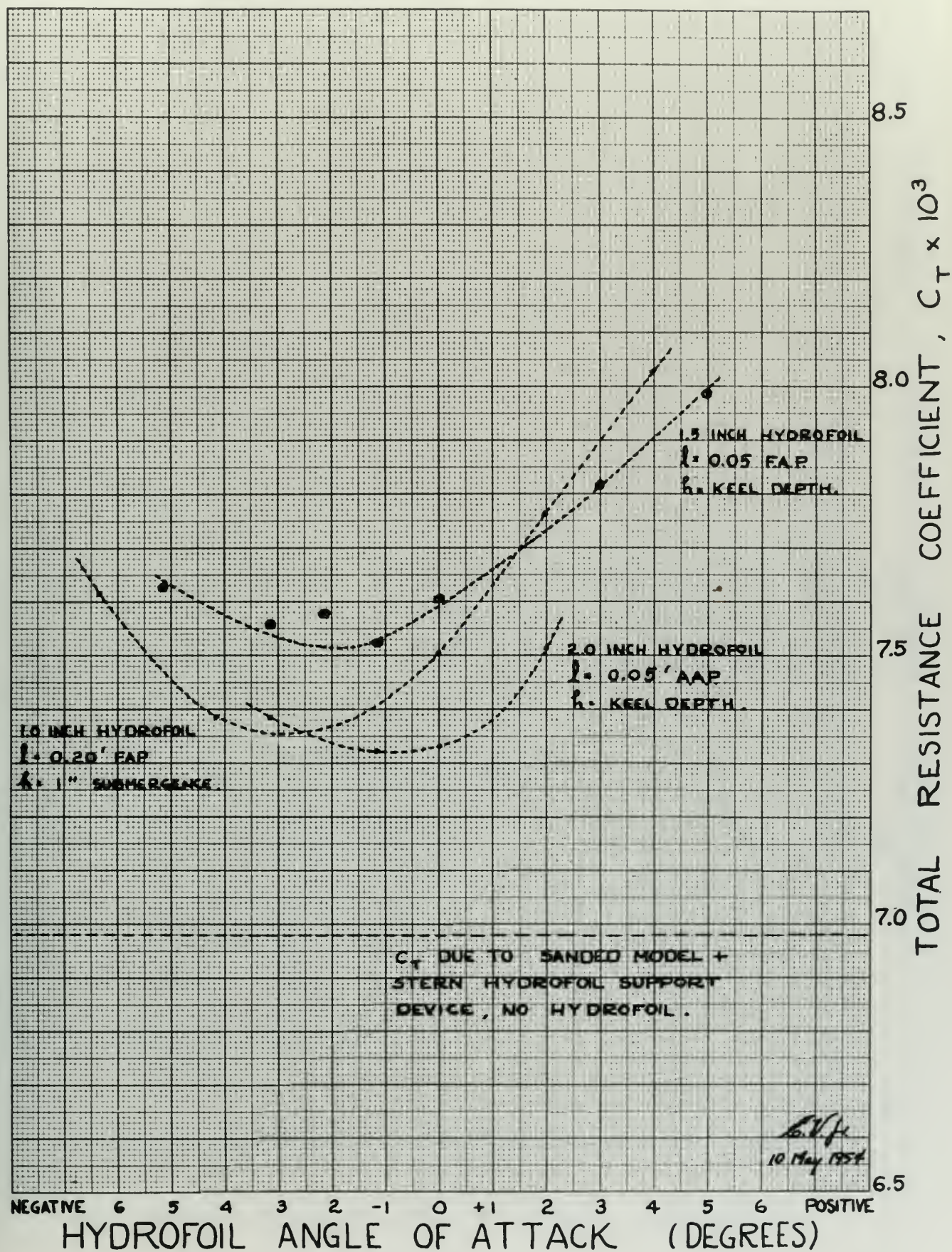




FIGURE XVIII.

OPTIMUM ANGLE OF ATTACK VS. CHORD LENGTH AT 32 KT. RG.

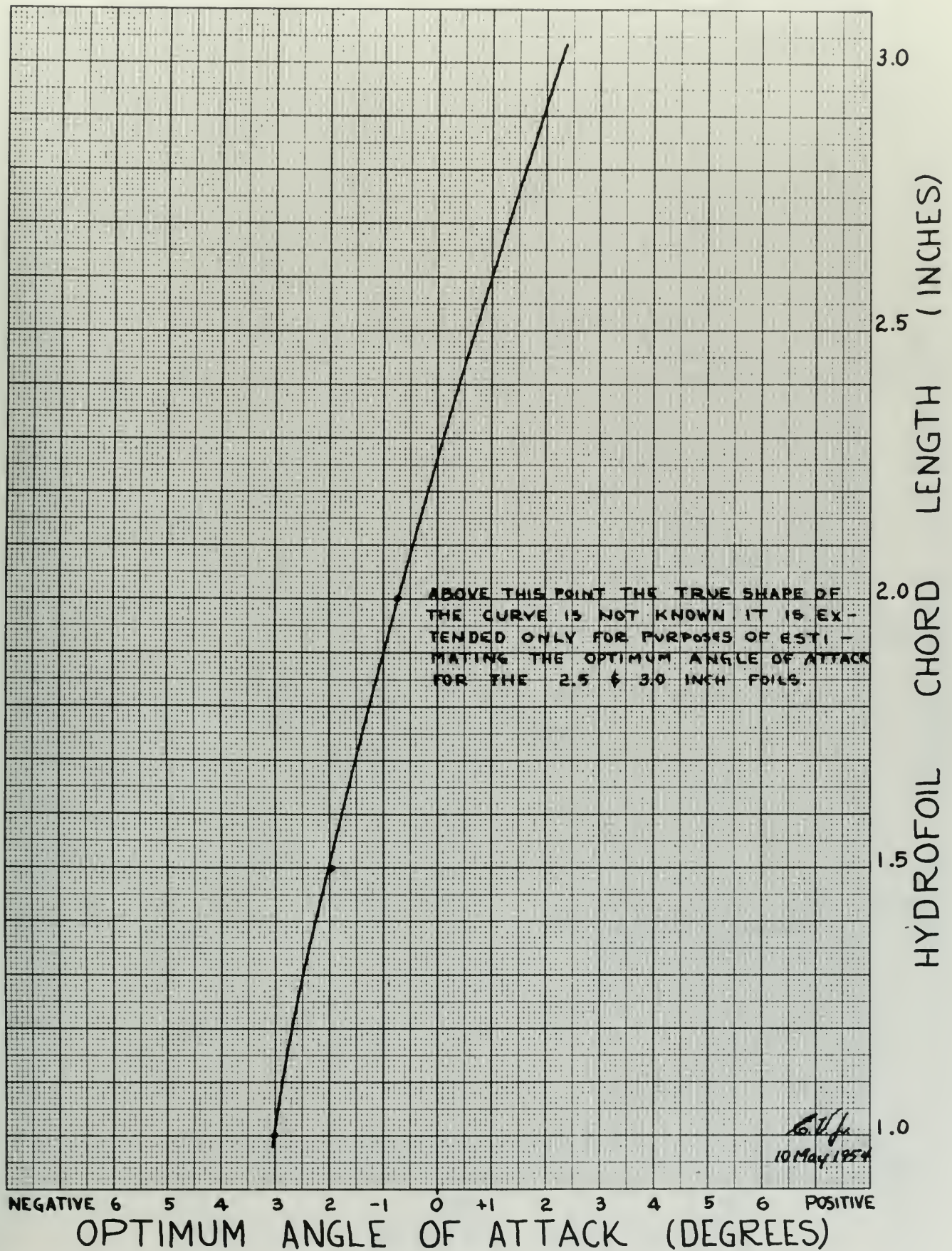




FIGURE XIX.

32¹KT. RG. OPTIMUM C_T VS. $V/\sqrt{L}$ CHARACTERISTICS FOR HYDROFOILS

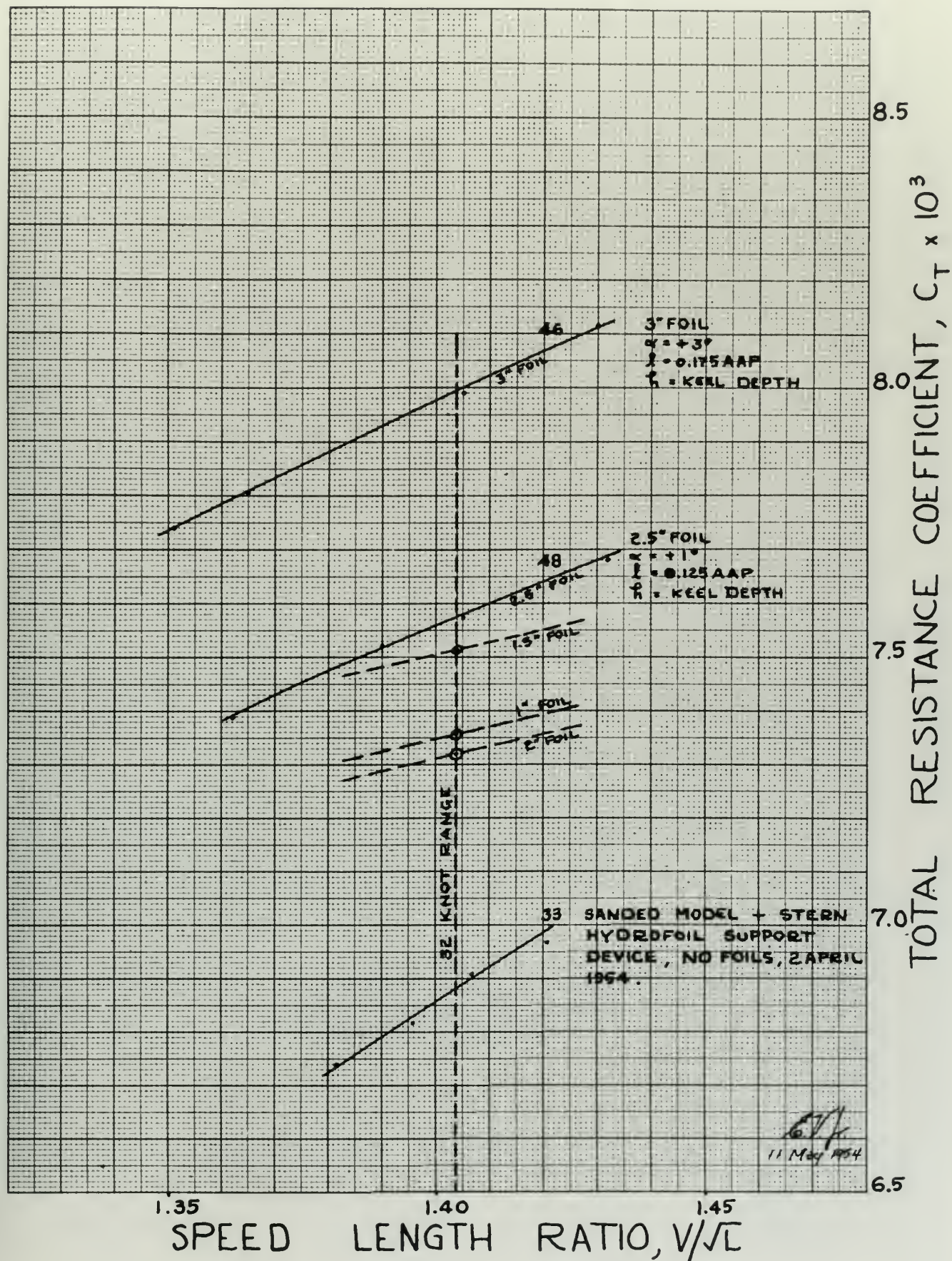




FIGURE XX.

CHORD LENGTH VS. MINIMUM C_T AT THE 32 KNOT RANGE ONLY

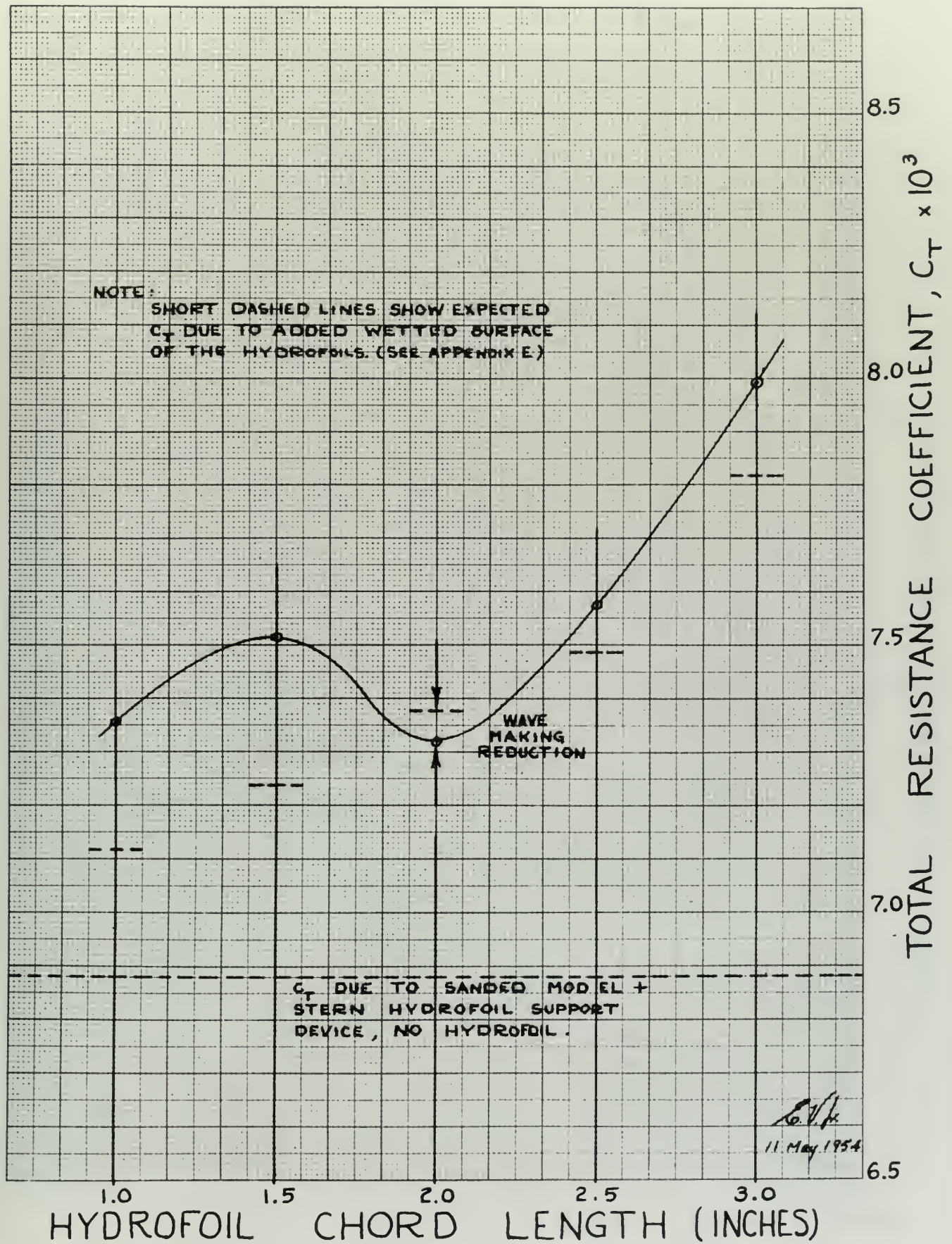




FIGURE XXI.

C_T VS. $V/\sqrt{L}$ AT 15 KT. RANGE FOR 1.0 AND 3.0 INCH HYDROFOILS

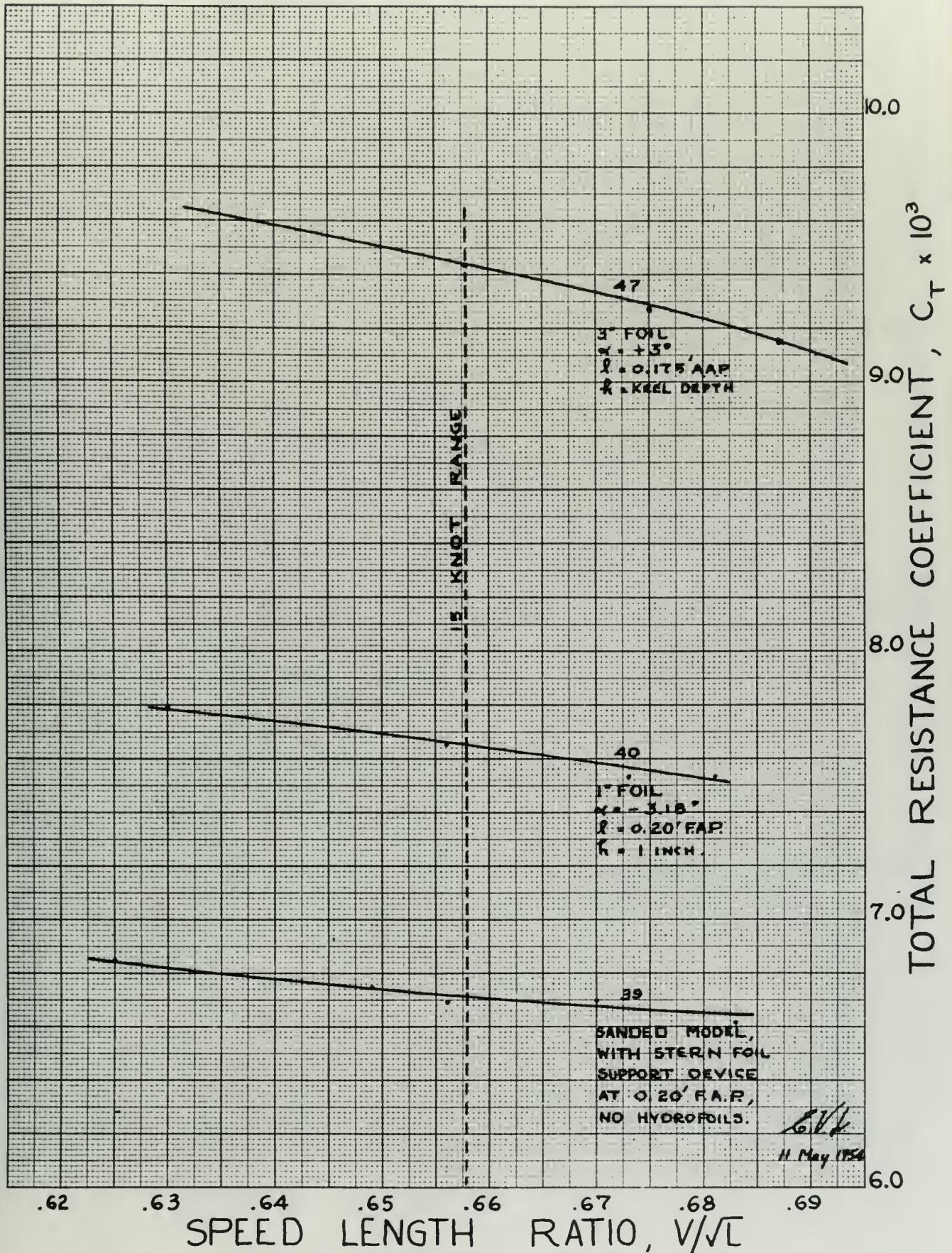




FIGURE XXII.

EFFECT ON RESISTANCE OF VARYING SUBMERGENCE
DEPTH OF THE 1.0 IN. HYDROFOIL AT THE 32 KT. RANGE

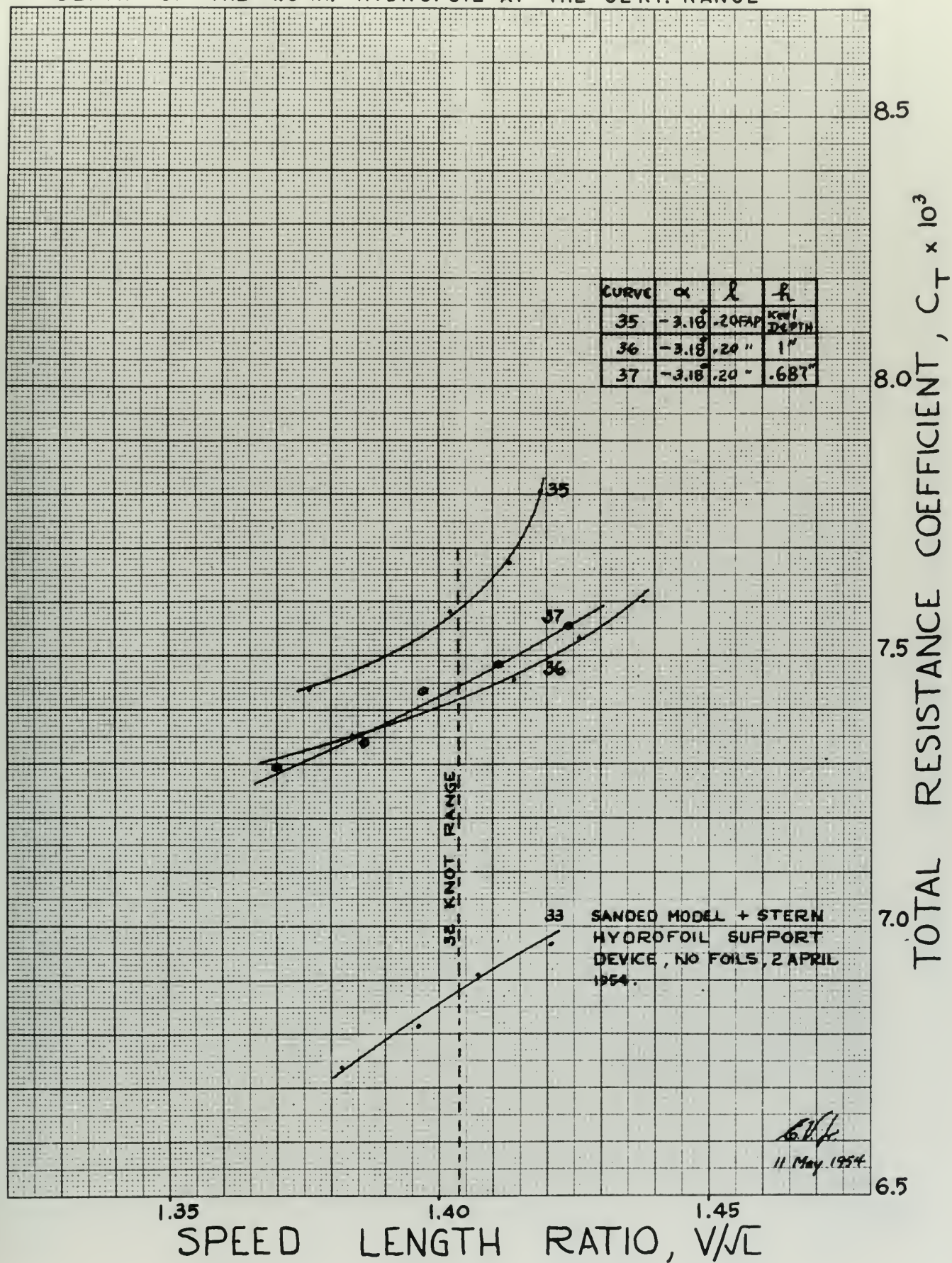




FIGURE XXIII.

32 KT. RANGE INTERCEPT CURVES FOR 2.0" BOW HYDROFOIL

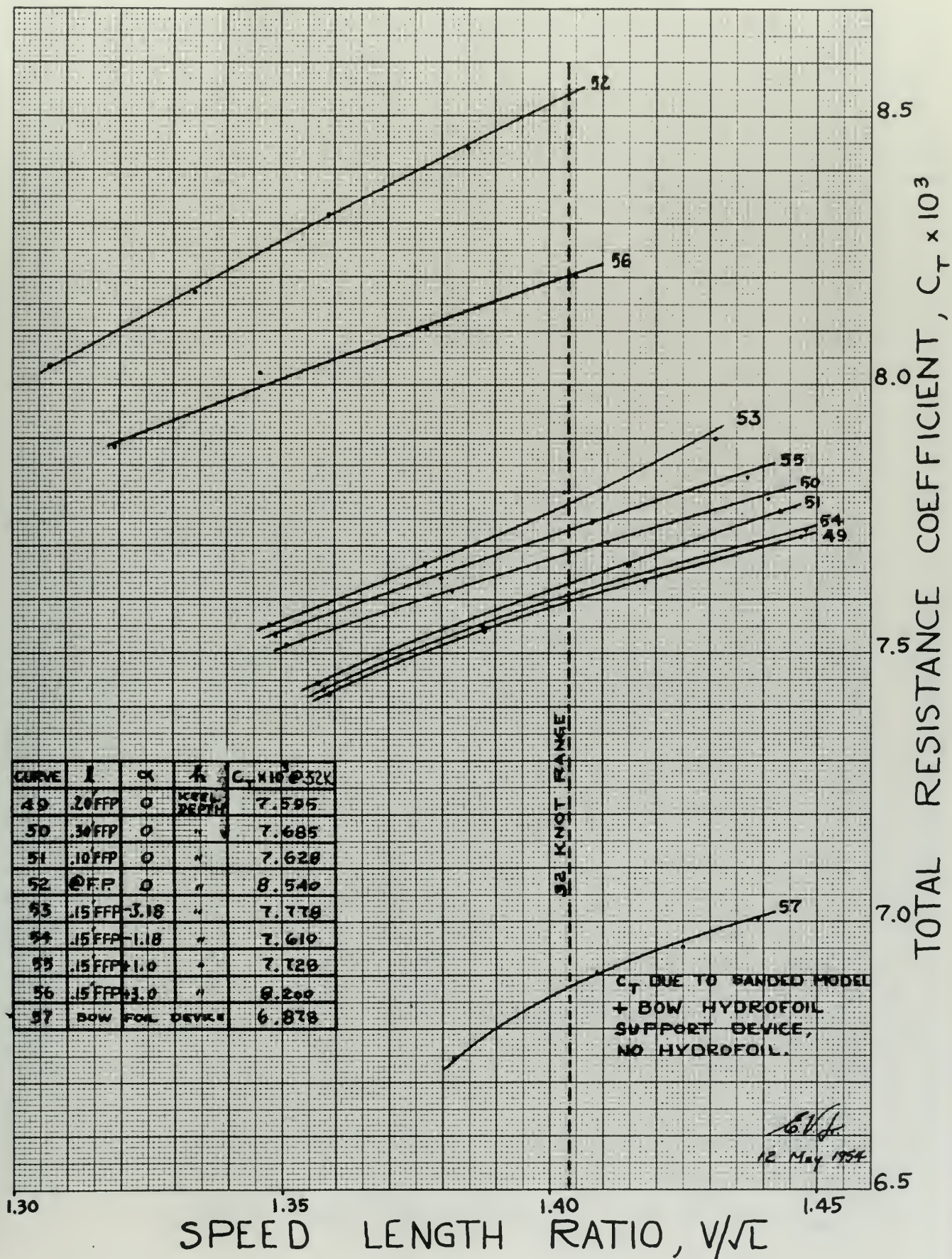




FIGURE XXIV .

VARIATION OF C_T WITH CHANGE OF POSITION OF THE 2.0" BOW HYDROFOIL AT THE 32KT. RANGE

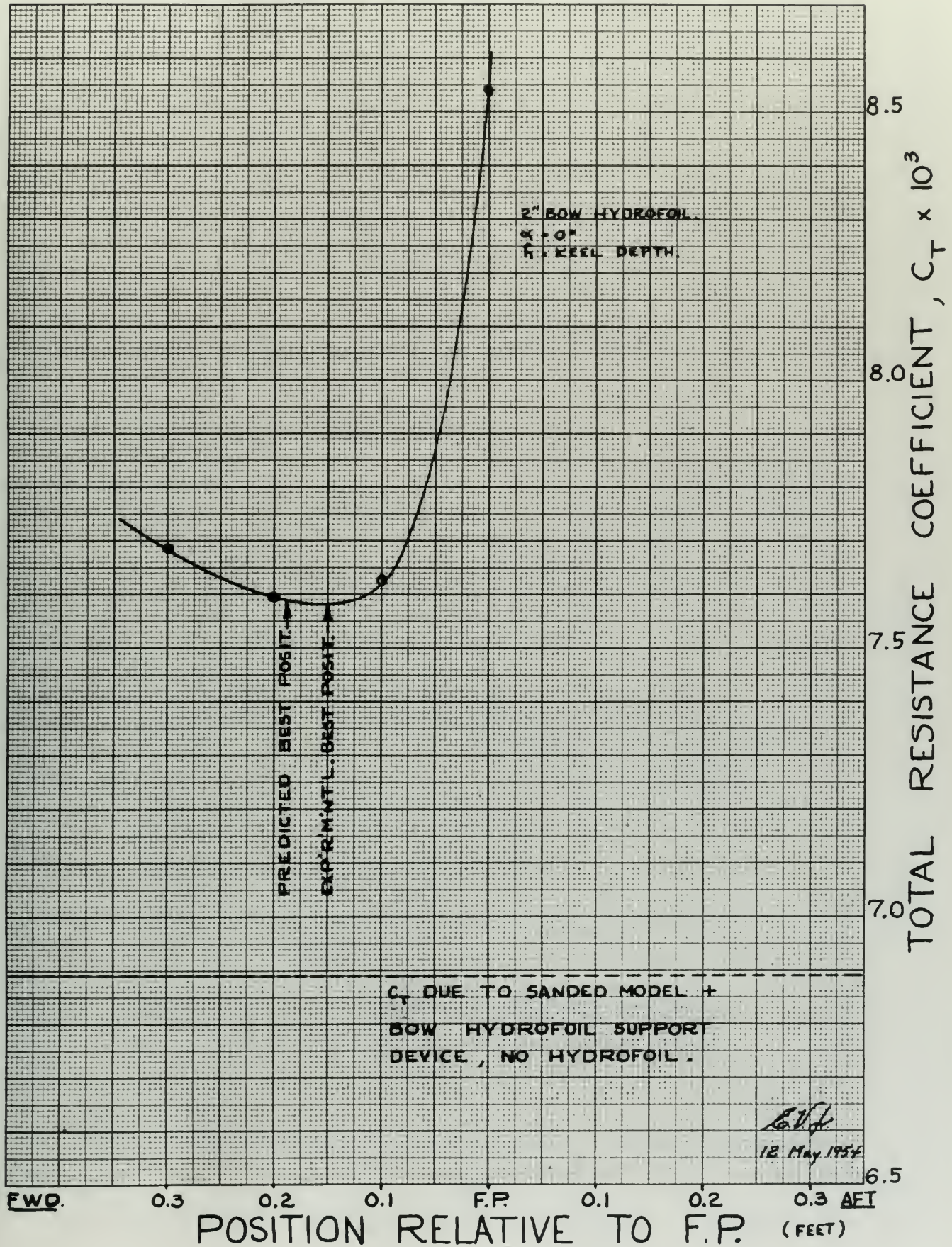
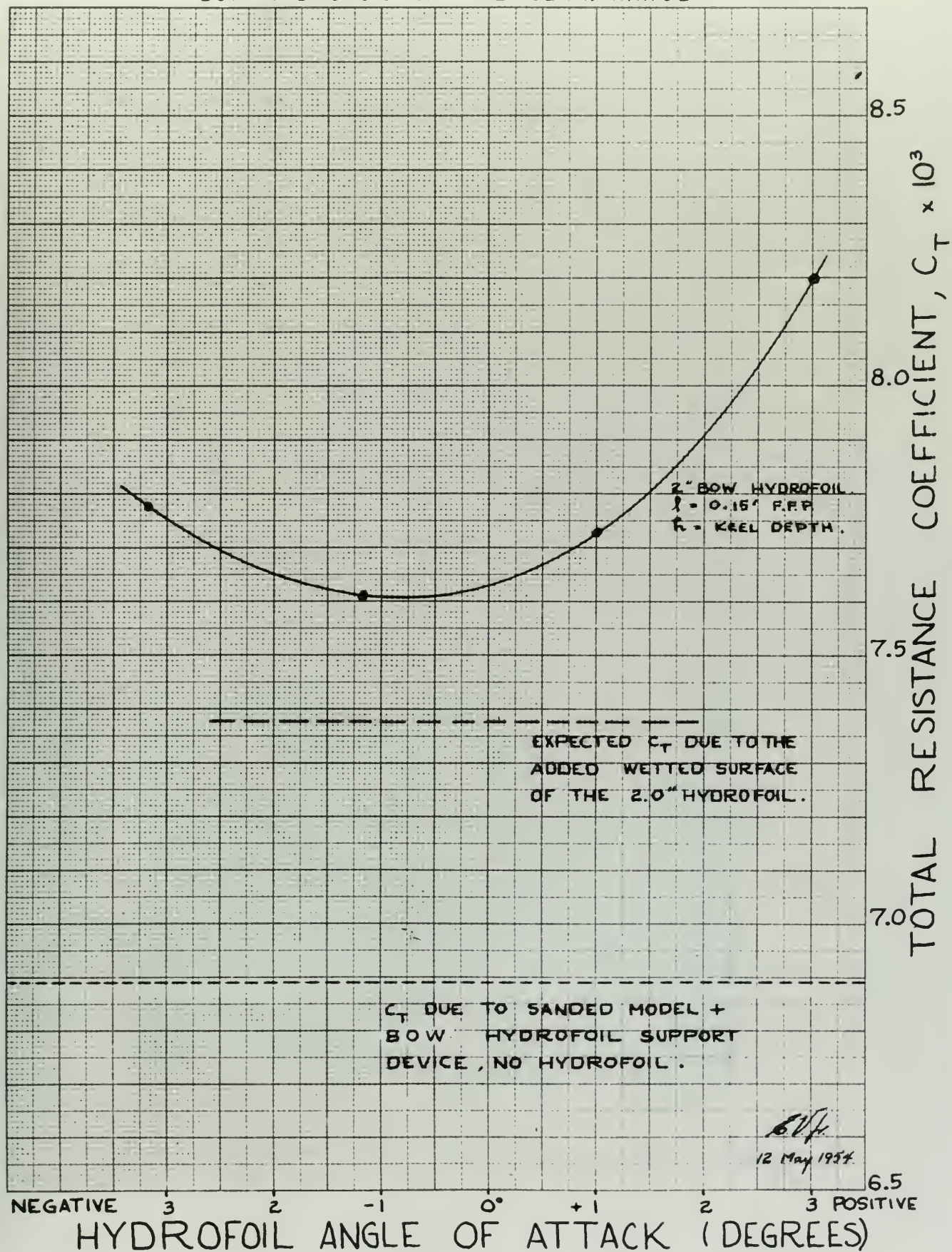




FIGURE XXV.

VARIATION OF C_T WITH CHANGE OF ATTACK ANGLE OF THE 2.0" BOW HYDROFOIL AT THE 32 KT. RANGE



IV. DISCUSSION OF RESULTS

A. Stern Hydrofoil Results

The presentation of the RESULTS section followed the chronological development of the thesis during the experimental testing stage. Accordingly, it is believed that a more pointed and well rounded analysis will result if this same chronological order is followed in this discussion.

The full range tests of C_T versus $V/\sqrt{L}$ as shown in Figure IX indicated that this particular vessel had a very well defined hump in its resistance curve that appeared to be of most significance near the 32 knot range. This of course inferred that the bow and stern transverse waves were somewhat in coincidence near this speed range. Reference (2) stated that "... the humps in the residual resistance curves occur when the surface levels about the stern are relatively low ..." and accordingly a photograph was made to verify this statement. (See Figure XXVI).

As will be noted in this photograph the surface level aft of the model is considerably disturbed by eddies, but the level is relatively low, and at worst

IV. DISCUSSION OF RESULTS

A. Steady Hydraulic Results

The presentation of the RESULTS section follows the chronological development of the thesis during the experimental testing stage. Accordingly, it is believed that a more pointed and well rounded analysis will result if the same chronological order is followed in this discussion.

The full range tests of C_T versus $V\sqrt{L}$ as shown in Figure IX indicated that this particular vessel had a very well defined hump in its resistance curve that appeared to be of most significance near the 32 knot range. This of course indicated that the bow and stern transverse waves were somewhat in coincidence near this speed range. Reference (1) stated that "... the humps in the residual resistance curves occur when the surface levels about the stern are relatively low ..." and accordingly a photograph was made to verify this statement. (See Figure XXVI).

As will be noted in this photograph the surface level aft of the model is considerably displaced by bowwaves, but the level is relatively low, and it must

FIGURE XXVI
Stern Wave Profile



Note wave hollow just aft of transom. Speed of model is 3.240 knots. (Corresponds to 35.5 knots for full size vessel).

there is only a very slight initial stern hallow. These facts tended to indicate that for this particular hull form the contribution to wave making by the after body was not nearly as significant as the contribution by the fore body. However, it remained for further testing to prove whether or not the effects of this after body contribution could be reduced by the presence of a properly positioned stern hydrofoil.

Before leaving Figure IX attention must also be focused on the changes in the sanded model's total resistance coefficient that occurred between the beginning of the testing period and the end. It will be noted that a marked increase in resistance took place, and this increase is attributed entirely to severe cracking of the paint on the bottom of the model. As the wood of the model was subjected to submersion and drying there was a resultant expansion and contraction. The bottom paint was an enamel or lacquer which was quite brittle in nature. As a consequence, it cracked, and the result was that there was a general roughening of the bottom surface.

The major portion of this cracking took place soon after the start of the testing program. Its presence was noted, but time prohibited the complete refinishing of the bottom, and the condition was accepted with full realization of its undesirability. It must be frankly

There is only a very slight lateral shift in the
 These facts taken in connection with the fact that
 will show the contraction of the body is not
 body was not really as significant as the contraction
 of the body. However, it remained for further
 feeling in some degree to see the effects of this
 what body contraction could be induced by the presence
 of a properly positioned strain hydralic.

Before leaving Figure 18 attention must also be
 focused on the changes in the strain hydralic wall
 resistance coefficient that occurred between the in-
 creasing of the body and the wall. It will be
 noted that a marked increase in resistance took place
 and this increase is attributed entirely to the
 stretching of the wall on the bottom of the vessel. As
 the wall of the vessel was subjected to compression and
 during there was a consistent expansion and contraction
 The bottom point was in contact with liquid which was quite
 elastic in nature. As a consequence, it stretched and the
 result was that there was a general expansion of the
 bottom surface.

The main portion of this stretching took place from
 after the start of the loading program. The pressure
 was added, and time required for complete relaxation
 of the bottom, and the contraction was constant after this
 relaxation of the vessel. It must be clearly

stated that this condition undoubtedly was not a static one, and hence some doubt arises as to the real condition that existed at any point in time during the testing program. It is the author's firm opinion that any error introduced by this source is of small significance and does not tend to invalidate any of the results of this thesis. (See Appendix II). The condition had reached its worst prior to tests on the hydrofoils, and furthermore, comparisons are made against the final evaluation of the total resistance coefficient of the roughened hull. Hence, due consideration for this condition has been exercised.

Turning now to the other curves, it will be noted that Figures X and XI are merely an evaluation of the added resistance that is caused by the support arms of the bow and stern hydrofoil support devices. This evaluation takes account of the roughened condition of the model's bottom as is indicated by the curves shown on the plots. These curves prove that the support arms do result in added resistance, and it would be incorrect to not consider this fact when analyzing the effects due to the hydrofoil alone.

Figures XII, XIII, and XIV could be combined into one single plot, but the result would be a mass confusion of 32 knot range intercept curves. It will be observed that the value of C_T at the 32 knot range for

[illegible]

any particular condition being considered is the desired information to be gained from all of the curves. Note that each curve has an identifying number which provides a key for establishing what conditions applied for that curve. (See Appendix D).

Figure XV, which shows the effect of longitudinal position on C_T for the 1.0, 1.5, and 2.0 inch foils, must not be considered as being indicative of the best results to be achieved with the stern hydrofoils. The curves on this plot are merely the result of varying one variable while the other two variables are held constant at values which are not necessarily the optimum for them. What is significant is the fact that chord length very definitely does have an effect on the proper positioning of a stern hydrofoil. As will be seen in Figure XVI, when the chord length is decreased, the hydrofoil should be moved forward with respect to the After Perpendicular. Conversely, an increase in chord length requires that the foil be moved further aft. Of some interest in Figure XV is the hump that occurs in the C_T versus Longitudinal Position curve for the 1.0 inch foil. This hump is believed due to the fact that when the 1.0 inch foil is located at 0.15 feet forward of the After Perpendicular it coincides almost exactly with the lowest point in the stern wave hollow. Therefore the local depth of submergence for the foil is not the optimum 1 inch, but is

any particular condition being considered in the present
 investigation it is found that all of the curves, both
 that with curve 10 in the vicinity of the origin and
 4.44 the corresponding curve in the vicinity of the origin
 curve (see Appendix T).
 Figure XV, which shows the effect of hydrostatic
 pressure on C_T for the 1.0, 1.5, and 2.0 inch coils
 and has been obtained as being indicative of the
 results to be obtained with the other hydrostatic
 curves of this kind and merely the result of varying the
 variable while the other two variables are held constant
 of coils which are not necessarily the system in which
 that is significant in the fact that coils having very
 different diameters have an effect on the proper positioning
 of a coil hydrostatic. As will be seen in Figure XVI,
 when the coil length is decreased, the hydrostatic curve
 is moved toward the right as the coil length decreases.
 Conversely, as pressure in each length increases the
 coil is moved toward the left as pressure increases in Figure
 XV is the same that occurs in the C_T versus hydrostatic
 position curve for the 1.0 inch coil. This curve is
 placed on the left side when the 1.0 inch coil is
 located at 0.12 inch below the other hydrostatic
 in which it is placed with the lowest curve in the
 figure with the other. Therefore the lower curve in the
 hydrostatic position curve is not the hydrostatic curve.

something less than this. Figure XXI definitely establishes that a submergence depth less than one chord will result in an increased value of C_T , hence this explanation for the hump seems plausible.

With the data gained from Figure XVI as to optimum longitudinal position for the 1.0, 1.5, and 2.0 inch foils it next followed that Figure XVII, C_T versus Hydrofoil Angle of Attack, would indicate two important pieces of information. These are the optimum angle of attack for each foil, and also whether or not any foil when located at its optimum longitudinal position and optimum angle of attack would result in a reduction of the model's C_T at the 32 knot range. As is quite readily seen in Figure XVII neither the 1.0, 1.5, nor 2.0 inch stern hydrofoil succeeded in reducing the model's C_T at the 32 knot range. It is to be remembered that the foils were at their optimum longitudinal positions, and were at either one chord length or at keel depth submergence, which meant they were optimally located from a submergence standpoint within the imposed limits that were discussed in the PROCEDURE. Therefore, on the basis of Figure XVII it appeared that stern hydrofoils could not effect an improvement in the wave making characteristics of this particular model.

Before terminating this discussion of Figure XVII, a most interesting point must be discussed. This point

[illegible]

is the fact that negative angles of attack for the three stern hydrofoils considered were found to be the optimum. While at first glance this may seem unusual, actually it is entirely to be expected. Figure III shows that this transom-stern model has a pronounced aft cut away area that begins near the aft one third length of the hull. As a consequence, the lines of flow in this aft area will tend to follow the upward sweep of the hull. Therefore, while a negative angle of attack with respect to the water surface might exist, locally the angle of attack was positive due to the direction of flow of the stream lines.

Now it is to be noted in Figure XVII that it was the 2.0 inch stern hydrofoil which resulted in the lowest C_T at its optimum angle of attack. This fact gave an impetus to continue the stern hydrofoil investigations by an analysis of the results which would be caused by the 2.5 and 3.0 inch hydrofoils when they were located at their optimum positions. In order to predict these optimum positions it was therefore necessary to develop Figure XVIII which shows the variations of optimum angle of attack with hydrofoil chord length. Before continuing the discussion of the 2.5 and 3.0 inch foils, note in Figure XVIII that as

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1-2 and 1-3 inch holes were in Figure XVII hole as
shown in Figure 1. Before mentioned the discussion of the
relationship of angles of attack with hydrofoil
necessity in moving Figure XVII with these the
needed these angles position of the hydrofoil
was located at these angles position. In order to
measure by the 1-2 and 1-3 inch hydrofoil were they
obtained by an analysis of the angles which were in
an analysis in showing the angles hydrofoil position
out of the optimum angle of attack. This last gave
the 1-2 inch hydrofoil angles repeated in the low
and it is as noted in Figure XVII hole as

chord length increases the optimum angle of attack changes from negative to positive. This would indicate that the larger foils are influenced by a type of streamline whose path diverges away from the upward sweep of the hull and then tends to become more nearly parallel to the undisturbed water surface. It is to be recalled that Figure XVI indicated that the large foils should be further aft of the A.P., and back in this area the foil will ride in the wake of the model. Figure XXVI showed this area to be quite disturbed by eddies; however, it is relatively level which would indicate that an imaginary laminar stream line in this turbulent area would most certainly not be directed upward as is the case beneath the transom of the model. Hence the indication that large chord length foils should be set at positive attack angles is quite reasonable.

Returning now to the 2.5 and 3.0 inch stern foils, their optimum positions were determined by extrapolation on Figures XVI and XVIII, and Figure XIX shows the C_T versus $V/\sqrt{L}$ characteristics caused by these foils. Also shown for comparison purposes are the same characteristics for the other foils when located at their optimum positions. It is readily apparent that the 2.5 and 3.0 inch foils failed to meet expectations and that the 2.0 inch foil was in reality the foil of optimum chord length.

could have been observed in the present state of affairs
 except from a position of elevation. This would indicate
 that the latter hills are not independent of a type of
 system, and those with elevations that have the general
 shape of the hills and that some of them were nearly
 parallel to the horizontal surface of the sea. It is to
 be recalled that Figure XVI indicated that the hills
 were about as high as the 4.5-4.6 and that in
 this case the hills will rise in the case of the model.
 Figure XVI showed that rise to be made distinct by
 adding, however, it is relatively level which would be
 places that an irregularly shaped area like in this
 equivalent area would not necessarily not be affected
 upward as is the case between the present and the model.
 Hence the indication that large hills would rise
 should be set as positive effect makes is quite
 reasonable.

According to the 4.5 and 4.6 from which hills
 their original position were determined by extrapolation
 on Figure XVI and XVII, and Figure XII shows the
 various VJ observations around the hills. Also
 shows the comparison between the same observations
 for the other hills when located at their original positions.
 It is readily apparent that the 4.5 and 4.6 hills
 failed to meet expectations and that the 4.6 hills
 are in reality the hills of highest elevation.

In Figure XX will be found a plot of stern hydrofoil chord length versus C_T . This curve more clearly establishes the fact that the 2.0 inch chord stern hydrofoil came closest to achieving a reduction in the C_T of the model at the 32 knot range. Furthermore, the curve also shows that the 2.0 inch foil was the only foil to achieve a reduction in wave making resistance. The short dashed lines at each chord length indicate the value of C_T that was to be expected if the model's wetted surface had been increased by an amount equal to that of each foil, and if the resistance caused by the stern hydrofoil support arms was also added to this. (For additional details, see Appendix F.)

The announced intentions of this thesis were to evaluate the effects of stern hydrofoils at both the 32 knot range and the 15 knot range. Following the unsuccessful attempts to reduce C_T in the 32 knot range, it was doubtful whether any improvement could be achieved in the 15 knot range. Figure XX has clearly indicated that the increases in frictional and form drag resistance as a result of the stern foils was in all cases greater than the reduction in wave making resistance. Therefore, since the 15 knot range was characterized by high frictional and low wave making resistance it seemed almost certain that no improvement was possible in the 15 knot range,

In figure 11 will be found a plot of $\log \frac{1}{C_T}$ versus $\log \frac{1}{C_T}$. The curve shows a linear relationship between $\log \frac{1}{C_T}$ and $\log \frac{1}{C_T}$. The slope of the line is 1.0, which is the expected value of C_T that was to be expected in the hydrolysis of the ester. The intercept of the line is 1.0, which is the expected value of C_T that was to be expected in the hydrolysis of the ester. The curve also shows that the 1.0 factor is the only factor that is involved in the reaction. The linear relationship between $\log \frac{1}{C_T}$ and $\log \frac{1}{C_T}$ is the expected value of C_T that was to be expected in the hydrolysis of the ester. The intercept of the line is 1.0, which is the expected value of C_T that was to be expected in the hydrolysis of the ester. The curve also shows that the 1.0 factor is the only factor that is involved in the reaction. The linear relationship between $\log \frac{1}{C_T}$ and $\log \frac{1}{C_T}$ is the expected value of C_T that was to be expected in the hydrolysis of the ester. The intercept of the line is 1.0, which is the expected value of C_T that was to be expected in the hydrolysis of the ester.

by use of stern hydrofoils. In order to prove the point, data was taken to provide the curves of Figure XXI. Only the 1.0 and 3.0 inch hydrofoils were considered, since they would serve to indicate the upper and lower limits of resistance that would result from a complete test of all five foils in the family. These foils were set at their optimum positions as found in the 32 knot range analysis, and as can be seen in Figure XXI no reduction in C_T at the 15 knot range was indicated as being possible.

One final point of discussion with regard to stern hydrofoils is centered upon the effects of submergence depth on the performance of a foil. As was mentioned in the PROCEDURE only the 1.0 inch foil was of small enough chord dimension to permit variation of the depth of submergence. Figure XXII shows the results that were achieved when this foil was tested at greater and less than one chord length depths as compared with the results achieved when set exactly at one chord length depth. As the curves clearly show a submergence greater than one chord length is more harmful than a submergence less than one chord length; additionally, one chord length appears to be the optimum depth of submergence for a hydrofoil to be employed as a wave making reduction device.

B. Bow Hydrofoil Results

As the final phase of this thesis, a limited investigation of results to be achieved with bow hydrofoils was made in order to establish if wave making resistance caused by the fore body was susceptible to reduction. Inasmuch as the 2.0 inch foil had given the best comparative results in the stern hydrofoil investigation, it was decided to use this foil in the bow hydrofoil investigation.

Figure XXIII shows the intercept curves that were used to establish the values of C_T at the 32 knot range for various positions of the bow hydrofoil. A predicted optimum longitudinal position of the hydrofoil was first computed. (See Appendix G.) Thereafter various longitudinal positions of the hydrofoil were examined and curve XXIV was developed to show the effect of variation of the longitudinal position upon C_T . It is interesting to note that the predicted best position was within 0.45 inches of the experimentally determined best position. Of particular significance is the sharp rise in C_T that occurred when the hydrofoil was positioned exactly at the Forward Perpendicular. Reference (9) had established the fact that a hydrofoil moving through water at a submergence depth less than one chord length would produce a surface disturbance immediately above the foil.

As the first stage in this process, the
 construction of a model of the system was
 made. This was done in order to determine the
 resistance caused by the flow of water in the
 system. The model was made of lead glass
 and the flow of water was measured in the
 system. It was found that the flow of water
 was not uniform in the system.

Figure XIII shows the resistance in the
 system at various values of Q and Q_0 . The
 flow of water was measured in the system. A
 system of resistance in the system was found
 to be proportional to the flow of water. The
 resistance in the system was found to be
 proportional to the flow of water.

Figure XIV shows the resistance in the
 system at various values of Q and Q_0 . The
 flow of water was measured in the system. It
 is found that the resistance in the system
 is proportional to the flow of water. The
 resistance in the system was found to be
 proportional to the flow of water.

On the basis of the results of the
 experiments, it was found that the flow of
 water in the system was not uniform. The
 flow of water was found to be proportional
 to the flow of water. The flow of water
 was found to be proportional to the flow of
 water. The flow of water was found to be
 proportional to the flow of water.

Now this very sharp rise in C_T is attributed to the fact that when the 2.0 inch foil was positioned exactly at the Forward Perpendicular it was at a submergence of 1.761 inches which was less than one chord length. Moreover, at this particular position it was immediately beneath the bulbous bow of the model. Accordingly, the effect of the hydrofoil was to cancel some of the beneficial effect achieved by the wave reducing properties of the bulbous bow. This cancellation was thus reflected in an increase in the value of C_T at the 32 knot range.

The angle of attack tests for the 2.0 inch bow hydrofoil, located at its optimum longitudinal position, established the very unexpected fact that the best angle of attack was negative and not positive. (See Figure XXV.) This is described as being unexpected because the optimum longitudinal position was found to be forward of the Forward Perpendicular where the lines of flow are not affected in any way by the hull as occurs under the after body. It is clear that the 2.0 inch bow hydrofoil failed to improve the wave making characteristics of the model, and so the negative angle of attack can only be explained by the fact that it undoubtedly caused the least form drag. As will be seen in Figure XXV this optimum angle was only $(-)0.65$ degrees which is quite small. Reference (11) indicates that the N.A.C.A. foil number 63₃-618 will

produce the least amount of form drag at a negative attack angle of one degree; hence, minimization of form drag required that the hydrofoil be set at a negative angle of attack.

C. Final Point of Discussion

To conclude this discussion attention is once more drawn to Figures XX and XXV. As was previously mentioned, the 2.0 inch stern hydrofoil was the only hydrofoil that achieved a wave making reduction. For all other foils, the fact that the measured values of C_T exceeded the maximum expected increase in C_T at the 32 knot range requires an explanation. (See Figure XX.)

The only logical explanation seems to be that the bow and stern hydrofoils produced a form drag and a surface wave disturbance which caused the increments of added resistance. These increments of added resistance due to form drag and surface wave disturbance were about the same for the 1.0 and 1.5 inch stern foils. However, for the 2.5 and 3.0 inch stern foils these increments tended to increase as chord length increased. The constancy of the increments for the smaller stern foils is explained by the fact that the 1.5 inch foil had greater wave reducing tendencies than the 1.0 inch foil; however,

the 1.5 inch foil also had greater form drag producing tendencies which apparently equalled the wave reducing tendencies. The result was that the 1.5 inch foil's increment remained the same. Now in the case of the 2.5 and 3.0 inch foils, they were carried much too close to the water surface, which meant ever-increasing surface-wave-disturbance tendencies. Additionally, as these foils increased in chord length they also increased in thickness, and consequently there was a progressive increase in form drag. The above, therefore, is proposed as one explanation for the failures of stern hydrofoils to improve C_T at the 32 knot range on this particular model.

The first thing I noticed when I stepped
out of the car was a sharp, cold wind.
The ground was covered in a thin layer of
snow. I looked around and saw that the
trees were bare and the sky was overcast.
I had heard that the weather was bad, but
I didn't realize it would be this cold.
I pulled my coat tighter and walked
towards the building. The door was open
and I saw a sign that said "Welcome".
I walked in and saw a receptionist.
She smiled at me and asked if I was
Mr. Smith. I nodded and she led me
to a room. I sat down and waited.
After a while, a man came in and
talked to me. He was friendly and
helpful. He showed me around the
building and answered my questions.
I was impressed by how well everything
was organized. I felt like I was in
a professional environment. I was
glad that I had come here. I was
going to have a good experience.

I was very happy to see that the
building was so nice. I was
impressed by the way everything was
organized. I felt like I was in a
professional environment. I was glad
that I had come here. I was going to
have a good experience. I was very
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nice. I was impressed by the way
everything was organized. I felt like
I was in a professional environment.
I was glad that I had come here. I
was going to have a good experience.

V. CONCLUSIONS

The most significant conclusion to be drawn from this investigation is that before applying stern hydrofoils to a hull form a careful evaluation of that form must take place. In general, if the hull form is very fine-lined, and if the stern wave disturbance is very small compared to that of the bow, it is doubtful whether stern hydrofoils can achieve a reduction in wave making resistance. In the model on which Mr. Kozlowski⁽⁷⁾ applied a stern hydrofoil, the longitudinal coefficient was 0.639. For the model employed in this investigation, the longitudinal coefficient was 0.572. Hence it is clear that stern hydrofoils are not suitable for application to extremely fine hull forms.

With regard to the use of bow hydrofoils on this particular hull form, it appears on the basis of a very limited investigation that possibly no benefit will result from such use. But this foregoing conclusion is subject to exception, for only one rectangular hydrofoil shape was investigated. Mr. Beal and Mr. Zakay⁽⁸⁾ have previously found that the swept back hydrofoil showed more promise than rectangular shaped hydrofoils. Further-

more, the process of a bulbous bow and a hydrofoil acting together, although not actually as one unit, suggests the desirability of further investigation.

The conclusions to be drawn as regards chord length, longitudinal position, angle of attack, and depth of submergence of stern hydrofoils can only be considered as being fully applicable to the hull form under consideration. Since no benefit was achieved by use of stern hydrofoils, the various tests carried out merely served to indicate what was the proper value of the variables so as to attain the least deleterious influence from the foil. However, with this reality in mind, it was found that a foil having a $(LBP)/(Chord\ Length)$ ratio of 25.99 was best. It is to be recalled that Mr. Kozlowski successfully employed a hydrofoil whose value for that ratio was 24.00.

With respect to longitudinal position of the stern hydrofoil, it was found that the proper position for the hydrofoil of optimum chord length (2 inches in this case) was at a position 1.0115(LBP) aft of the Forward Perpendicular.

As regards angle of attack for the optimum foil, the correct angle is best described by the ratio, $(Keel\ cut\ away\ angle)/(hydrofoil\ angle\ of\ attack)$. This ratio is used because in the area immediately beneath a transom stern, the lines of flow for the water

1. The first step is to identify the problem. This involves understanding the situation, the people involved, and the resources available. It is important to gather all relevant information and to define the problem clearly.

2. The second step is to analyze the problem. This involves breaking the problem down into smaller, more manageable parts. It is important to identify the causes of the problem and to determine the scope of the problem.

3. The third step is to develop a plan. This involves determining the steps that need to be taken to solve the problem. It is important to consider all possible solutions and to choose the one that is most effective.

4. The fourth step is to implement the plan. This involves putting the plan into action. It is important to monitor the progress of the plan and to make adjustments as needed.

5. The fifth step is to evaluate the results. This involves assessing the effectiveness of the plan and the impact of the solution. It is important to determine whether the problem has been solved and to identify any lessons learned.

passing along the hull will follow the general upward sweep of the underbody. Hence, the best angle of attack for a stern hydrofoil will be a function of the upsweep of the hull and the flow lines following this change in form. The local direction of flow thus establishes the proper angle of attack, even though it may be negative with respect to the horizontal. For the model of this investigation, the ratio has been found to be $(-).13$. The minus sign, of course, indicates that the angle of attack was negative for the reasons given above.

Concerning the optimum depth of submergence, it appears that one chord length is the optimum depth. More harmful effects will result from placing the foil too deep than will result from locating it at less than one chord length in depth.

VI. RECOMMENDATIONS FOR FUTURE RESEARCH

As was evidenced by the data obtained for the 2 inch stern hydrofoil, and also as a result of Mr. Kozlowski's work⁽⁷⁾, it has definitely been established that stern hydrofoils will reduce stern wave making resistance. The degree of reduction appears to be a function of the hull form of the vessel being considered.

In order to verify this last statement, it is suggested that the lines for a full bodied ship having the same displacement and wetted surface as the prototype in this investigation be developed. This of course will be a shorter, beamier, and possibly deeper hull form.

After the model for this new form has been built, it is recommended that a hydrofoil from the family tested in this thesis then be attached to the stern of this new model. It is further recommended that the size of the model should be considered very carefully before development of the lines in order to closely approximate the $(LBP)/(Chord\ Length)$ ratio of 24 to 26.

As a first trial, the selected hydrofoil might be positioned on the basis of the experimental results

given in the CONCLUSIONS section of this thesis.

As a final word of advice, it is recommended that extreme care be exercised in the design of a towing bracket as well as for a support device for the hydrofoil. Any model towed at high speed in the M.I.T. Towing Tank is subject to possible yawing if the towing bracket is even slightly misaligned.

Further, if the hydrofoil is not completely level in the transverse direction, it will act like an airplane wing which has a dihedral angle in one wing but none in the other. The result is that the model is caused to heel because the components of lift are not symmetrical and tend to produce an unbalanced heeling moment.

In conclusion, it is recommended that extreme care be exercised to keep the inside of the model dry while testing. Also, brittle lacquer or enamel type paints should be avoided.

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12. Ward, M. History of the
Ward family from the first
settling in 1637 to the
present time. Boston, 1897.

APPENDIX A

Characteristics of Model DTMB-DD 332 and
Model 17 of Mr. Kozlowski

A. X. 1000

Classification of cases in the
order of the year, 1900-1901

APPENDIX A

Characteristics of Model DTMB-DD 332 (ASW-Transom Stern)

<u>Item</u>	<u>Model</u>	<u>Ship</u>
Length between perpendiculars	4.333 ft.	520 ft.
Beam	0.446 ft.	53.5 ft.
Draft	0.147 ft.	17.6 ft.
Displacement	7.63 lb. F.W.	6540 tons S.W.
Wetted Surface	2.028 sq.ft.	29200 sq.ft.
Designed Speed	2.920 knots	32.0 knots

Designed Speed Length Ratio = 1.402

Longitudinal Coefficient = 0.572

$$\frac{\Delta}{\left(\frac{L}{100}\right)^3} = 46.51$$

Scale Ratio = 120

APPENDIX A

Classification of the data (see Table 1)

Item	Value	Unit
1. Initial speed of the car	1.440	m/s
2. Final speed of the car	0.170	m/s
3. Distance traveled	1.440	m
4. Time taken	0.170	s
5. Acceleration	1.440	m/s ²
6. Deceleration	0.170	m/s ²
7. Total distance	1.440	m
8. Total time	0.170	s

Initial speed of the car = 1.440 m/s

Final speed of the car = 0.170 m/s

$$\frac{1}{100} = \frac{1}{100} \times 100$$

100 = 100

APPENDIX A Con'd

Characteristics of Model 17 (Destroyer) used by
Mr. Kozlowski

<u>Item</u>	<u>Model</u>	<u>Ship</u>
Length between perpendiculars	5.3 ft.	369 ft.
Beam	0.604 ft.	40.5 ft.
Draft	0.216 ft.	13.4 ft.
Displacement	21.09 lb.F.W.	2844 Tons S.W.
Wetted Surface		
(a) Naked Model	3.524 sq.ft.	15,860 sq.ft.
(b) Model with Hydrofoil	3.680 sq.ft.	16,564 sq.ft.
Designed Speed	4.26 knots	35 knots

Designed Speed Length Ratio = 1.82

Longitudinal Coefficient = 0.639

$$\frac{\Delta}{\left(\frac{L}{100}\right)^3} = 56.3$$

Scale Ratio = 67.091

APPENDIX B

N.A.C.A. Air Foil Shapes Recommended for Hydro-
foil Research.

APPENDIX B

Table B.1. All State Income Tax Rates for 1994

Table B.2. All State Income Tax Rates for 1995

Table B.3. All State Income Tax Rates for 1996

Table B.4. All State Income Tax Rates for 1997

Table B.5. All State Income Tax Rates for 1998

Table B.6. All State Income Tax Rates for 1999

Table B.7. All State Income Tax Rates for 2000

APPENDIX B

List of N.A.C.A. Air Foil Shapes Suitable for Use in Hydrofoil Research

The following N.A.C.A. shapes have characteristics closely approximating those of N.A.C.A. foil number 63₃-618. The page number following each foil is the location of data for the foil in N.A.C.A. Report No. 824 of 1945.

1.	N.A.C.A.	4412	p. 141
2.	"	63 ₂ -215	167
3.	"	63 ₄ -421	176
4.	"	64 ₃ -418	194
5.	"	64 ₃ -618	195
6.	"	64 ₄ -421	198
7.	"	65 ₃ -618	225

APPENDIX B

LIST OF NAMES AND FULL NAMES CONTAINED IN THE
IN SPECIALIZED NETWORK

The following names were listed in the
classified newspaper index in 1947. Full names
are given. The page number following each name is the
page on which the name is listed in the index.

of 1947

Full Name	Page	Initials	Page
John Doe	100	J.D.	100
John Doe	101	J.D.	101
John Doe	102	J.D.	102
John Doe	103	J.D.	103
John Doe	104	J.D.	104
John Doe	105	J.D.	105
John Doe	106	J.D.	106

APPENDIX C

Details of N.A.C.A. Foil No. 63₃-618

- (a) Explanation of designation.
- (b) Basic offset constants for foil shape.
- (c) Location of foil support points.
- (d) Use of sandstrips on foils.

APPENDIX C

Table C-1. List of Sites

- (a) Location of Site
- (b) Name of Site
- (c) Location of Site
- (d) Name of Site

APPENDIX C

Details of N.A.C.A. Foil No. 63₃-618.

A. Explanation of Designation 63₃-618

The numbers are treated in the order in which they appear from left to right.

6: This is the series designation.

3: This denotes the chordwise position of minimum pressure in tenths of the chord behind the leading edge for the basic symmetrical section at zero lift.

Subscript 3: A N.A.C.A. identifying number which indicates the low drag range to distinguish the foil from earlier airfoils.

6: This is the design lift coefficient in tenths.

18: These two digits indicate the airfoil thickness in per cent of the chord.

B. Basic Offset Constants Used in Arriving at the Shape of the Foil

First, it is necessary to define two terms.

Mean Line: This is a line which lies midway between the upper and lower surface of the foil. It does not coincide with the chord line unless the foil is a symmetrical shape.

APPENDIX C

DETAILS OF THE LATERAL WALLS OF THE

A. Description of the Lateral Wall

The structure is shown in the plan view in which they

appear from the side.

It is a concrete structure.

It is a concrete structure which is shown in the plan view in which they appear from the side. It is a concrete structure which is shown in the plan view in which they appear from the side.

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B. Description of the Lateral Wall

It is a concrete structure which is shown in the plan view in which they appear from the side.

It is a concrete structure which is shown in the plan view in which they appear from the side. It is a concrete structure which is shown in the plan view in which they appear from the side.

Basic Thickness Form: This is a term used to describe the thickness of the foil at points along the mean line. The longitudinal or x coordinate establishes the position of a point on the mean line. The y coordinate designates the symmetrical thickness about the mean line along a line perpendicular to the mean line. This line passes through the given x coordinate intercept on the mean line.

Meanline Data

<u>x</u>	<u>y</u>
0	0
1.25	0.489
2.5	0.958
5.0	1.833
7.5	2.625
10	3.333
15	4.50
20	5.333
25	5.833
30	6.000
40	5.878
50	5.510
60	4.898
70	4.041
80	2.939
90	1.592
100	0

Basic Thickness Form Data

<u>x</u>	<u>y</u>
0	0
1.25	2.217
2.5	3.104
5	4.362
7.5	5.308
10	6.068
15	7.225
20	8.048
25	8.600
30	8.913
40	8.845
50	7.942
60	6.455
70	4.622
80	2.691
90	0.985
100	0

The above x and y coordinates are expressed as percentages of the chord.

Additionally:

Leading Edge Radius = 2.12% of chord

Slope of Radius Through Leading Edge = 0.2527% of chord.

The shape of a N.A.C.A. 63₅-618 foil may be seen in Figure V. In the foreground of this figure will be seen an unfinished 1.0 inch chord foil as it is received after cutting in the Slean Laboratory Machine Shop.

C. Location of Support Points for Hydrofoils

For all foils the support point was located on the mean line at 25% of the chord aft of the leading edge. This position roughly approximates the general longitudinal location of the center of lift as the angle of attack is varied. All longitudinal positions of the foil refer to the location of this support point.

D. Use of Sandstrips on Hydrofoils

The question arose as to the need for sandstrips on the hydrofoils in order to insure turbulent flow conditions around the foil. For tests in the 32 knot range, the local Reynolds number for the 2 inch foil was 7.75×10^4 . At this particular range of Reynolds number the frictional resistance coefficient for laminar flow is greater than that for turbulent flow. Accordingly, by not using sandstrips and allowing laminar flow on the submerged hydrofoil, the possible beneficial results produced by the hydrofoil are penalized. The result is

a greater percentage amount of resistance caused by friction than would be the case for full sized turbulent conditions. Accordingly, if the hydrofoils did produce beneficial results in the model tests, one would know that even better results were possible in the full size ship where conditions were turbulent and a smaller frictional coefficient existed.

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APPENDIX D

Test Data and Calculated Results

TEST NO. 1

Date: 12 February 1954

Temperature of Water: 66°F (The water in the M.I.T.
Towing Tank is fresh water)Purpose of Test: Evaluation of C_T versus $V/\sqrt{L}$ for unsanded,
naked hull.

Location of Plot: Figure IX, Curve 1.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F	$V/\sqrt{L}$
1	0.010	0.615	0.006	2.728	0.296
2	0.020	0.770	0.016	4.671	0.370
3	0.030	0.946	0.026	5.035	0.455
4	0.040	1.117	0.035	5.300	0.537
5	0.050	1.270	0.045	4.942	0.610
6	0.060	1.407	0.055	4.904	0.676
7	0.070	1.536	0.065	4.859	0.738
8	0.080	1.651	0.075	4.847	0.793
9	0.090	1.760	0.084	4.822	0.846
10	0.100	1.870	0.094	4.873	0.899
11	0.110	1.962	0.104	4.793	0.943
12	0.120	2.057	0.114	4.776	0.989
13	0.130	2.141	0.124	4.792	1.029
14	0.140	2.227	0.134	4.782	1.070
15	0.150	2.292	0.144	4.849	1.101
16	0.160	2.365	0.154	4.868	1.136
17	0.170	2.425	0.164	4.932	1.165
18	0.180	2.473	0.174	5.029	1.188
19	0.190	2.523	0.184	5.106	1.212
20	0.200	2.568	0.194	5.200	1.234
21	0.210	2.607	0.204	5.304	1.253
22	0.220	2.645	0.214	5.407	1.271
23	0.230	2.682	0.223	5.504	1.289
24	0.280	2.835	0.273	6.032	1.362
25	0.320	2.970	0.313	6.296	1.427

Table 1 shows the results of the analysis of variance for the data presented in Table 1. The results are presented in the form of a table with 5 columns: Source of Variation, Degrees of Freedom, Mean Square, F-value, and Probability > F. The results are presented for the analysis of variance for the data presented in Table 1.

Source of Variation	Degrees of Freedom	Mean Square	F-value	Probability > F
1	1	0.000	0.000	0.999
2	1	0.000	0.000	0.999
3	1	0.000	0.000	0.999
4	1	0.000	0.000	0.999
5	1	0.000	0.000	0.999
6	1	0.000	0.000	0.999
7	1	0.000	0.000	0.999
8	1	0.000	0.000	0.999
9	1	0.000	0.000	0.999
10	1	0.000	0.000	0.999
11	1	0.000	0.000	0.999
12	1	0.000	0.000	0.999
13	1	0.000	0.000	0.999
14	1	0.000	0.000	0.999
15	1	0.000	0.000	0.999
16	1	0.000	0.000	0.999
17	1	0.000	0.000	0.999
18	1	0.000	0.000	0.999
19	1	0.000	0.000	0.999
20	1	0.000	0.000	0.999
21	1	0.000	0.000	0.999
22	1	0.000	0.000	0.999
23	1	0.000	0.000	0.999
24	1	0.000	0.000	0.999
25	1	0.000	0.000	0.999

TEST NO. 2

Date: 20 February 1954

Temperature of Water: 66.5°F

Purpose of Test: Completion of the C_T versus $V/\sqrt{L}$ test
for unsanded, naked hulls.

Location of Plot: Figure IX, Curve 1.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_{T \times 10^3}$ at 70°F.	$V/\sqrt{L}$
1	0.095	1.818	0.090	4.795	0.874
2	0.100	1.871	0.094	4.776	0.899
3	0.105	1.915	0.099	4.800	0.920
4	0.145	2.274	0.139	4.757	1.093
5	0.150	2.320	0.144	4.738	1.115
6	0.155	2.350	0.149	4.775	1.129
7	0.240	2.710	0.233	5.640	1.302
8	0.250	2.742	0.243	5.745	1.318
9	0.260	2.770	0.253	5.859	1.331
10	0.270	2.794	0.263	5.990	1.343
11	0.290	2.858	0.283	6.160	1.373
12	0.300	2.901	0.293	6.189	1.394
13	0.310	2.920	0.303	6.317	1.403
14	0.320	2.971	0.313	6.297	1.428
15	0.330	2.993	0.323	6.400	1.438
16	0.340	3.033	0.333	6.424	1.458
17	0.350	3.066	0.343	6.575	1.473

TEST NO. 3

Date: 27 February 1954

Temperature of Water: 68.8°F.

Purpose of Test: Evaluation of added resistance resulting from stern hydrofoil support device located at After Perpendicular. Model equipped with sandstrips on bow.

Location of Plots: Runs 1-6, Figure X, curve 2.
Runs 7-16, Figure XI, curve 3.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.040	1.044	0.035	5.784	0.502
2	0.050	1.190	0.045	5.684	0.572
3	0.055	1.260	0.050	5.620	0.606
4	0.060	1.325	0.055	5.588	0.637
5	0.065	1.386	0.060	5.562	0.666
6	0.070	1.448	0.065	5.513	0.696
7	0.270	2.747	0.263	6.220	1.320
8	0.290	2.810	0.283	6.397	1.350
9	0.300	2.838	0.293	6.490	1.364
10	0.310	2.869	0.303	6.567	1.379
11	0.320	2.897	0.313	6.652	1.392
12	0.330	2.926	0.323	6.725	1.406
13	0.340	2.957	0.333	6.788	1.421
14	0.350	2.993	0.343	6.823	1.438
15	0.360	3.028	0.353	6.861	1.455
16	0.370	3.046	0.363	6.973	1.464

UNIT 17 - 1001
 Location of River: 1001
 Date: 1001
 Name: 1001
 Location of River: 1001
 Date: 1001
 Name: 1001

Run	Applied Force (lb)	Power (hp)	Resistance (lb)	Time (sec)	Work (ft-lb)
1	0.000	1.000	0.000	0.000	0.000
2	0.000	1.000	0.000	0.000	0.000
3	0.000	1.000	0.000	0.000	0.000
4	0.000	1.000	0.000	0.000	0.000
5	0.000	1.000	0.000	0.000	0.000
6	0.000	1.000	0.000	0.000	0.000
7	0.000	1.000	0.000	0.000	0.000
8	0.000	1.000	0.000	0.000	0.000
9	0.000	1.000	0.000	0.000	0.000
10	0.000	1.000	0.000	0.000	0.000
11	0.000	1.000	0.000	0.000	0.000
12	0.000	1.000	0.000	0.000	0.000
13	0.000	1.000	0.000	0.000	0.000
14	0.000	1.000	0.000	0.000	0.000
15	0.000	1.000	0.000	0.000	0.000
16	0.000	1.000	0.000	0.000	0.000

TEST NO. 4

Date: 6 March 1854

Temperature of Water: 67°F

Purpose of Test: Evaluation of added resistance due to
attaching sandstrips to naked hull.

Location of Plot: Figure IX, curve 4.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_{T \times 10^3}$ at 70°F.	$V/\sqrt{L}$
1	0.370	3.105	0.363	6.638	1.492
2	0.360	3.065	0.353	6.676	1.473
3	0.350	3.057	0.343	6.520	1.469
4	0.340	3.018	0.333	6.493	1.450
5	0.330	2.995	0.323	6.396	1.439
6	0.320	2.938	0.313	6.447	1.412
7	0.310	2.908	0.303	6.373	1.397
8	0.300	2.880	0.293	6.286	1.384
9	0.290	2.847	0.283	6.213	1.368
10	0.280	2.815	0.273	6.130	1.353
11	0.270	2.782	0.263	6.045	1.337
12	0.260	2.748	0.253	5.960	1.320
13	0.250	2.714	0.243	5.869	1.304
14	0.230	2.646	0.224	5.668	1.272
15	0.340	2.999	0.333	6.576	1.441
16	0.210	2.569	0.204	5.476	1.234
17	0.190	2.482	0.184	5.294	1.193
18	0.170	2.377	0.164	5.146	1.142
19	0.150	2.240	0.144	5.093	1.076
20	0.130	2.081	0.124	5.085	1.000
21	0.110	1.910	0.104	5.074	0.918
22	0.090	1.708	0.085	5.143	0.821
23	0.070	1.488	0.065	5.201	0.715
24	0.050	1.225	0.045	5.338	0.589
25	0.040	1.075	0.035	5.430	0.517
26	0.030	0.910	0.026	5.480	0.437
27	0.020	0.719	0.016	5.415	0.346
28	0.010	0.459	0.006	5.113	0.221

TABLE 1. - SUMMARY OF DATA FOR THE MONTHS OF JANUARY AND FEBRUARY, 1940. (Continued from page 10)

STATION	DATE	WIND SPEED (M.P.H.)	WIND DIRECTION	WAVE HEIGHT (FEET)	SEA STATE
1	1/1	10	090	1.0	1
1	1/2	12	090	1.0	1
1	1/3	15	090	1.0	1
1	1/4	18	090	1.0	1
1	1/5	20	090	1.0	1
1	1/6	22	090	1.0	1
1	1/7	25	090	1.0	1
1	1/8	28	090	1.0	1
1	1/9	30	090	1.0	1
1	1/10	32	090	1.0	1
1	1/11	35	090	1.0	1
1	1/12	38	090	1.0	1
1	1/13	40	090	1.0	1
1	1/14	42	090	1.0	1
1	1/15	45	090	1.0	1
1	1/16	48	090	1.0	1
1	1/17	50	090	1.0	1
1	1/18	52	090	1.0	1
1	1/19	55	090	1.0	1
1	1/20	58	090	1.0	1
1	1/21	60	090	1.0	1
1	1/22	62	090	1.0	1
1	1/23	65	090	1.0	1
1	1/24	68	090	1.0	1
1	1/25	70	090	1.0	1
1	1/26	72	090	1.0	1
1	1/27	75	090	1.0	1
1	1/28	78	090	1.0	1
1	1/29	80	090	1.0	1
1	1/30	82	090	1.0	1
1	1/31	85	090	1.0	1
2	2/1	88	090	1.0	1
2	2/2	90	090	1.0	1
2	2/3	92	090	1.0	1
2	2/4	95	090	1.0	1
2	2/5	98	090	1.0	1
2	2/6	100	090	1.0	1
2	2/7	102	090	1.0	1
2	2/8	105	090	1.0	1
2	2/9	108	090	1.0	1
2	2/10	110	090	1.0	1
2	2/11	112	090	1.0	1
2	2/12	115	090	1.0	1
2	2/13	118	090	1.0	1
2	2/14	120	090	1.0	1
2	2/15	122	090	1.0	1
2	2/16	125	090	1.0	1
2	2/17	128	090	1.0	1
2	2/18	130	090	1.0	1
2	2/19	132	090	1.0	1
2	2/20	135	090	1.0	1
2	2/21	138	090	1.0	1
2	2/22	140	090	1.0	1
2	2/23	142	090	1.0	1
2	2/24	145	090	1.0	1
2	2/25	148	090	1.0	1
2	2/26	150	090	1.0	1
2	2/27	152	090	1.0	1
2	2/28	155	090	1.0	1
2	2/29	158	090	1.0	1
2	2/30	160	090	1.0	1
2	2/31	162	090	1.0	1

TEST NO. 5

Date: 20 March 1954

Temperature of Water: 61.5°F.

Purpose of Test: Determination of optimum longitudinal position for the 2 inch stern hydrofoil, with $\alpha = +7^\circ$, and $h =$ keel depth, for all runs. Sandstrips on bow. Support device at stern.

Details and Location of Each Plot:

Runs 1-5, for $l=0.063$ ft. F.A.P., curve 5Runs 6-10, for $l=0.038$ ft. A.A.P., curve 6Runs 11-15, for $l=0.163$ ft. F.A.P., curve 7Runs 16-20, for $l=0.138$ ft. A.A.P., curve 8

Each of the Above Curves will be found in Figure XIV.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.370	2.855	0.363	7.869	1.372
2	0.370	2.911	0.383	7.988	1.399
3	0.400	2.937	0.393	8.050	1.411
4	0.410	2.960	0.403	8.127	1.422
5	0.420	2.990	0.413	8.162	1.437
6	0.420	3.009	0.413	8.058	1.446
7	0.410	2.965	0.403	8.100	1.425
8	0.400	2.948	0.393	7.990	1.417
9	0.390	2.920	0.383	7.939	1.403
10	0.370	2.866	0.363	7.809	1.377
11	0.370	2.848	0.363	7.907	1.369
12	0.390	2.905	0.383	8.023	1.396
13	0.400	2.935	0.393	8.062	1.410
14	0.410	2.961	0.403	8.123	1.423
15	0.420	2.988	0.413	8.173	1.436
16	0.420	2.989	0.413	8.168	1.436
17	0.410	2.963	0.403	8.111	1.424
18	0.400	2.938	0.393	8.047	1.412
19	0.390	2.910	0.383	7.995	1.398
20	0.370	2.855	0.363	7.869	1.372

TEST NO. 6

Date: 21 March 1954

Temperature of Water: 63.5°F.

Purpose of Test: Determination of optimum longitudinal position for the 1.5 inch stern hydrofoil, with $\alpha = +7^\circ$, and $h =$ keel depth, for all runs. Sandstrips on bow. Support device at stern.

Details and Location of each Plot:

Runs 1-5, for $l=0.063$ ft. F.A.P., curve 9Runs 6-10, for $l=0.036$ ft. A.A.P., curve 10Runs 11-15, for $l=0.163$ ft. F.A.P., curve 11Runs 16-20, for $l=0.138$ ft. A.A.P., curve 12

Each of the Above Curves will be found in Figure XIII.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.400	2.951	0.393	7.995	1.418
2	0.390	2.920	0.383	7.959	1.403
3	0.370	2.895	0.363	7.675	1.391
4	0.410	2.980	0.403	8.039	1.432
5	0.360	2.835	0.353	7.782	1.362
6	0.360	2.834	0.353	7.786	1.362
7	0.370	2.860	0.363	7.864	1.374
8	0.390	2.915	0.383	7.985	1.401
9	0.400	2.945	0.393	8.028	1.415
10	0.410	2.974	0.403	8.072	1.429
11	0.410	2.975	0.403	8.066	1.430
12	0.400	2.947	0.393	8.015	1.416
13	0.390	2.913	0.383	7.997	1.400
14	0.370	2.857	0.363	7.882	1.373
15	0.360	2.826	0.353	7.832	1.358
16	0.360	2.805	0.353	7.899	1.348
17	0.370	2.832	0.363	7.969	1.361
18	0.390	2.889	0.383	8.083	1.388
19	0.400	2.916	0.393	8.137	1.401
20	0.410	2.944	0.403	8.239	1.415

TEST NO. 7

Date: 24 March 1954

Temperature of Water: 65.8°F.

Purpose of Test: Determination of the optimum angle of attack for the 1.5 inch stern hydrofoil with $l=0.05$ ft. R.A.P., and h = keel depth, for all runs. Sandstrips on bow. Support device at stern.

Details and Location of Each Plot:

Runs 1-4, for $\alpha = 0^\circ$, curve 13Runs 5-8, for $\alpha = 3^\circ$, curve 14Runs 9-11, for $\alpha = 5^\circ$, curve 15Runs 12-15, for $\alpha = -1.18^\circ$, curve 16

Each of the Above Curves will be found in Figure XIII.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.360	2.887	0.353	7.522	1.387
2	0.370	2.915	0.363	7.587	1.401
3	0.390	2.970	0.383	7.706	1.427
4	0.400	3.005	0.393	7.720	1.444
5	0.400	2.972	0.393	7.898	1.428
6	0.390	2.942	0.383	7.857	1.414
7	0.370	2.886	0.363	7.742	1.387
8	0.360	2.858	0.353	7.675	1.373
9	0.360	2.836	0.353	7.795	1.363
10	0.370	2.861	0.363	7.879	1.375
11	0.390	2.919	0.383	7.983	1.403
12	0.400	3.007	0.393	7.710	1.445
13	0.390	2.979	0.383	7.659	1.432
14	0.370	2.925	0.363	7.531	1.406
15	0.360	2.891	0.353	7.501	1.389

TEST NO. 8

Date: 26 March 1954

Temperature of Water: 66°F.

Purpose of Test: Completion of tests for determining the optimum angle of attack for the 1.5 inch stern hydrofoil with $l = 0.05$ ft. F.A.P. and $h =$ keel depth, for all runs. Sandstrips on bow. Support device at stern.

Details and Location of Each Plot:

Runs 1-5, for $\alpha = -3.18^\circ$, curve 17.Runs 6-9, for $\alpha = -5.18^\circ$, curve 18.

Each of the Above Curves will be found in Figure XIII.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.360	2.895	0.353	7.491	1.391
2	0.370	2.910	0.363	7.621	1.398
3	0.390	2.975	0.383	7.686	1.430
4	0.400	3.003	0.393	7.737	1.443
5	0.370	2.915	0.363	7.594	1.401
6	0.360	2.891	0.353	7.509	1.389
7	0.370	2.913	0.363	7.605	1.400
8	0.390	2.966	0.383	7.734	1.425
9	0.400	2.989	0.393	7.814	1.436

TEST NO. 9

Date: 27 March 1954

Temperature of Water: 66.5°F.

Purpose of Tests: A. Completion of optimum angle of attack tests for the 1.5 inch stern hydrofoil, with $l = 0.05$ ft. F.A.P., $\alpha = -2.18^\circ$, h = keel depth; see runs 1-4, as listed below.

B. Beginning of optimum longitudinal position tests for the 1.0 inch stern hydrofoil with $h = 1$ inch submergence, and $\alpha = -2.18^\circ$; see runs 5-29.

Details and Location of Each Plot: Runs 1-4, for 1.5 inch foil, see A. above, plotted as curve 19 in Figure XIII.

The following runs pertain to the 1.0 inch stern hydrofoil; their curves will be found in Figure XII.

Runs 5-9, for $l = 0.15$ ft. F.A.P., curve 20

Runs 10-14, for $l = 0.25$ ft. F.A.P., curve 21

Runs 15-19, for $l = 0.35$ ft. F.A.P., curve 22

Runs 20-24, for $l = 0.425$ ft. F.A.P., curve 23

Runs 25-29, for $l = 0.150$ ft. F.A.P., curve 24

Model equipped with sandstrips on bow, with support device at stern.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.400	3.011	0.393	7.700	1.447
2	0.390	2.976	0.383	7.686	1.430
3	0.370	2.919	0.363	7.577	1.403
4	0.360	2.890	0.353	7.521	1.389
5	0.360	2.895	0.353	7.493	1.391
6	0.370	2.925	0.363	7.454	1.406
7	0.390	2.984	0.383	7.645	1.434
8	0.400	3.012	0.393	7.694	1.447
9	0.380	2.955	0.373	7.592	1.420
10	0.360	2.902	0.353	7.456	1.395

(continued)

TEST NO. 9 (continued)

Date: 27 March 1954

Pun No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
11	0.370	2.994	0.363	7.497	1.410
12	0.380	2.962	0.373	7.557	1.423
13	0.390	2.989	0.383	7.618	1.436
14	0.400	3.012	0.393	7.694	1.447
15	0.360	2.900	0.353	7.467	1.393
16	0.370	2.930	0.363	7.517	1.408
17	0.380	2.952	0.373	7.609	1.419
18	0.385	2.974	0.378		1.429
19	0.400	3.012	0.393	7.694	1.447
20	0.360	2.873	0.353	7.609	1.381
21	0.370	2.902	0.363	7.668	1.395
22	0.380	2.935	0.383	7.906	1.410
23	0.390	2.959	0.383	7.776	1.422
24	0.400	2.989	0.393	7.818	1.436
25	0.360	2.898	0.353	7.477	1.393
26	0.370	2.925	0.363	7.545	1.406
27	0.380	2.939	0.373	7.678	1.412
28	0.390	2.981	0.383	7.660	1.432
29	0.400	2.995	0.393	7.784	1.439

Year	Age (yr)	Length (cm)	Weight (kg)	Condition factor	Sex
1970	1	100.0	0.5	0.05	M
1970	2	110.0	0.8	0.06	F
1970	3	120.0	1.2	0.07	M
1970	4	130.0	1.8	0.08	F
1970	5	140.0	2.5	0.09	M
1970	6	150.0	3.5	0.10	F
1970	7	160.0	4.8	0.11	M
1970	8	170.0	6.5	0.12	F
1970	9	180.0	8.5	0.13	M
1970	10	190.0	11.0	0.14	F
1970	11	200.0	14.0	0.15	M
1970	12	210.0	17.5	0.16	F
1970	13	220.0	21.5	0.17	M
1970	14	230.0	26.0	0.18	F
1970	15	240.0	31.0	0.19	M
1970	16	250.0	36.5	0.20	F
1970	17	260.0	42.5	0.21	M
1970	18	270.0	49.0	0.22	F
1970	19	280.0	56.0	0.23	M
1970	20	290.0	63.5	0.24	F
1970	21	300.0	71.5	0.25	M
1970	22	310.0	80.0	0.26	F
1970	23	320.0	89.0	0.27	M
1970	24	330.0	98.5	0.28	F
1970	25	340.0	108.5	0.29	M
1970	26	350.0	119.0	0.30	F
1970	27	360.0	130.0	0.31	M
1970	28	370.0	141.5	0.32	F
1970	29	380.0	153.5	0.33	M
1970	30	390.0	166.0	0.34	F
1970	31	400.0	179.0	0.35	M
1970	32	410.0	192.5	0.36	F
1970	33	420.0	206.5	0.37	M
1970	34	430.0	221.0	0.38	F
1970	35	440.0	236.0	0.39	M
1970	36	450.0	251.5	0.40	F
1970	37	460.0	267.5	0.41	M
1970	38	470.0	284.0	0.42	F
1970	39	480.0	301.0	0.43	M
1970	40	490.0	318.5	0.44	F
1970	41	500.0	336.5	0.45	M
1970	42	510.0	355.0	0.46	F
1970	43	520.0	374.0	0.47	M
1970	44	530.0	393.5	0.48	F
1970	45	540.0	413.5	0.49	M
1970	46	550.0	434.0	0.50	F
1970	47	560.0	455.0	0.51	M
1970	48	570.0	476.5	0.52	F
1970	49	580.0	498.5	0.53	M
1970	50	590.0	521.0	0.54	F
1970	51	600.0	544.0	0.55	M
1970	52	610.0	567.5	0.56	F
1970	53	620.0	591.5	0.57	M
1970	54	630.0	616.0	0.58	F
1970	55	640.0	641.0	0.59	M
1970	56	650.0	666.5	0.60	F
1970	57	660.0	692.5	0.61	M
1970	58	670.0	719.0	0.62	F
1970	59	680.0	746.0	0.63	M
1970	60	690.0	773.5	0.64	F
1970	61	700.0	801.5	0.65	M
1970	62	710.0	830.0	0.66	F
1970	63	720.0	859.0	0.67	M
1970	64	730.0	888.5	0.68	F
1970	65	740.0	918.5	0.69	M
1970	66	750.0	949.0	0.70	F
1970	67	760.0	980.0	0.71	M
1970	68	770.0	1011.5	0.72	F
1970	69	780.0	1043.5	0.73	M
1970	70	790.0	1076.0	0.74	F
1970	71	800.0	1109.0	0.75	M
1970	72	810.0	1142.5	0.76	F
1970	73	820.0	1176.5	0.77	M
1970	74	830.0	1211.0	0.78	F
1970	75	840.0	1246.0	0.79	M
1970	76	850.0	1281.5	0.80	F
1970	77	860.0	1317.5	0.81	M
1970	78	870.0	1354.0	0.82	F
1970	79	880.0	1391.0	0.83	M
1970	80	890.0	1428.5	0.84	F
1970	81	900.0	1466.5	0.85	M
1970	82	910.0	1505.0	0.86	F
1970	83	920.0	1544.0	0.87	M
1970	84	930.0	1583.5	0.88	F
1970	85	940.0	1623.5	0.89	M
1970	86	950.0	1664.0	0.90	F
1970	87	960.0	1705.0	0.91	M
1970	88	970.0	1746.5	0.92	F
1970	89	980.0	1788.5	0.93	M
1970	90	990.0	1831.0	0.94	F
1970	91	1000.0	1874.0	0.95	M
1970	92	1010.0	1917.5	0.96	F
1970	93	1020.0	1961.5	0.97	M
1970	94	1030.0	2006.0	0.98	F
1970	95	1040.0	2051.0	0.99	M
1970	96	1050.0	2096.5	1.00	F
1970	97	1060.0	2142.5	1.01	M
1970	98	1070.0	2189.0	1.02	F
1970	99	1080.0	2236.0	1.03	M
1970	100	1090.0	2283.5	1.04	F
1970	101	1100.0	2331.5	1.05	M
1970	102	1110.0	2380.0	1.06	F
1970	103	1120.0	2429.0	1.07	M
1970	104	1130.0	2478.5	1.08	F
1970	105	1140.0	2528.5	1.09	M
1970	106	1150.0	2579.0	1.10	F
1970	107	1160.0	2630.0	1.11	M
1970	108	1170.0	2681.5	1.12	F
1970	109	1180.0	2733.5	1.13	M
1970	110	1190.0	2786.0	1.14	F
1970	111	1200.0	2839.0	1.15	M
1970	112	1210.0	2892.5	1.16	F
1970	113	1220.0	2946.5	1.17	M
1970	114	1230.0	3001.0	1.18	F
1970	115	1240.0	3056.0	1.19	M
1970	116	1250.0	3111.5	1.20	F
1970	117	1260.0	3167.5	1.21	M
1970	118	1270.0	3224.0	1.22	F
1970	119	1280.0	3281.0	1.23	M
1970	120	1290.0	3338.5	1.24	F
1970	121	1300.0	3396.5	1.25	M
1970	122	1310.0	3455.0	1.26	F
1970	123	1320.0	3514.0	1.27	M
1970	124	1330.0	3573.5	1.28	F
1970	125	1340.0	3633.5	1.29	M
1970	126	1350.0	3694.0	1.30	F
1970	127	1360.0	3755.0	1.31	M
1970	128	1370.0	3816.5	1.32	F
1970	129	1380.0	3878.5	1.33	M
1970	130	1390.0	3941.0	1.34	F
1970	131	1400.0	4004.0	1.35	M
1970	132	1410.0	4067.5	1.36	F
1970	133	1420.0	4131.5	1.37	M
1970	134	1430.0	4196.0	1.38	F
1970	135	1440.0	4261.0	1.39	M
1970	136	1450.0	4326.5	1.40	F
1970	137	1460.0	4392.5	1.41	M
1970	138	1470.0	4459.0	1.42	F
1970	139	1480.0	4526.0	1.43	M
1970	140	1490.0	4593.5	1.44	F
1970	141	1500.0	4661.5	1.45	M
1970	142	1510.0	4730.0	1.46	F
1970	143	1520.0	4799.0	1.47	M
1970	144	1530.0	4868.5	1.48	F
1970	145	1540.0	4938.5	1.49	M
1970	146	1550.0	5009.0	1.50	F
1970	147	1560.0	5080.0	1.51	M
1970	148	1570.0	5151.5	1.52	F
1970	149	1580.0	5223.5	1.53	M
1970	150	1590.0	5296.0	1.54	F
1970	151	1600.0	5369.0	1.55	M
1970	152	1610.0	5442.5	1.56	F
1970	153	1620.0	5516.5	1.57	M
1970	154	1630.0	5591.0	1.58	F
1970	155	1640.0	5666.0	1.59	M
1970	156	1650.0	5741.5	1.60	F
1970	157	1660.0	5817.5	1.61	M
1970	158	1670.0	5894.0	1.62	F
1970	159	1680.0	5971.0	1.63	M
1970	160	1690.0	6048.5	1.64	F
1970	161	1700.0	6126.5	1.65	M
1970	162	1710.0	6205.0	1.66	F
1970	163	1720.0	6284.0	1.67	M
1970	164	1730.0	6363.5	1.68	F
1970	165	1740.0	6443.5	1.69	M
1970	166	1750.0	6524.0	1.70	F
1970	167	1760.0	6605.0	1.71	M
1970	168	1770.0	6686.5	1.72	F
1970	169	1780.0	6768.5	1.73	M
1970	170	1790.0	6851.0	1.74	F
1970	171	1800.0	6934.0	1.75	M
1970	172	1810.0	7017.5	1.76	F
1970	173	1820.0	7101.5	1.77	M
1970	174	1830.0	7186.0	1.78	F
1970	175	1840.0	7271.0	1.79	M
1970	176	1850.0	7356.5	1.80	F
1970	177	1860.0	7442.5	1.81	M
1970	178	1870.0	7529.0	1.82	F
1970	179	1880.0	7616.0	1.83	M
1970	180	1890.0	7703.5	1.84	F
1970	181	1900.0	7791.5	1.85	M
1970	182	1910.0	7880.0	1.86	F
1970	183	1920.0	7969.0	1.87	M
1970	184	1930.0	8058.5	1.88	F
1970	185	1940.0	8148.5	1.89	M
1970	186	1950.0	8239.0	1.90	F
1970	187	1960.0	8330.0	1.91	M
1970	188	1970.0	8421.5	1.92	F
1970	189	1980.0	8513.5	1.93	M
1970	190	1990.0	8606.0	1.94	F
1970	191	2000.0	8700.0	1.95	M
1970	192	2010.0	8794.5	1.96	F
1970	193	2020.0	8889.5	1.97	M
1970	194	2030.0	8985.0	1.98	F
1970	195	2040.0	9081.0	1.99	M
1970	196	2050.0	9177.5	2.00	F
1970	197	2060.0	9274.5	2.01	M
1970	198	2070.0	9372.0	2.02	F
1970	199	2080.0	9470.0	2.03	M
1970	200	2090.0	9568.5	2.04	F
1970	201	2100.0	9667.5	2.05	M
1970	202	2110.0	9767.0	2.06	F
1970	203	2120.0	9867.0	2.07	M
1970	204	2130.0	9967.5	2.08	F
1970	205	2140.0	10068.5	2.09	M
1970	206	2150.0	10170.0	2.10	F
1970	207	2160.0	10272.0	2.11	M
1970	208	2170.0	10374.5	2.12	F
1970	209	2180.0	10477.5	2.13	M
1970	210	2190.0	10581.0	2.14	F
1970	211	2200.0	10685.0	2.15	M
1970	212	2210.0	10789.5	2.16	F
1970	213	2220.0	10894.5	2.17	M
1970	214	2230.0	10999.5	2.18	F
1970	215	2240.0	11105.0	2.19	M
1970	216	2250.0	112		

TEST NO. 10

Date: 28 March 1954

Temperature of Water: 66.8°F.

Purpose of Test: Completion of optimum longitudinal position tests for the 1.0 inch stern hydrofoil with $h = 1$ inch submergence, and $\alpha = -2.12^\circ$. Sand strips on bow, Support device at stern.

Details and Location of Each Plot:

Runs 1-5, for $l = 0.05$ ft. A.A.P., curve 25

Runs 6-10 for $l = 0.15$ ft. A.A.P., curve 26

Runs 11-15 for $l = 0.30$ ft. A.A.P., curve 27

Runs 16-19 for $l = 0.20$ ft. F.A.P., curve 28

Each of the Above Curves will be found in Figure XII.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.360	2.899	0.353	7.475	1.393
2	0.370	2.926	0.363	7.543	1.406
3	0.380	2.955	0.373	7.596	1.420
4	0.390	2.990	0.383	7.615	1.437
5	0.400	3.017	0.393	7.670	1.450
6	0.360	2.888	0.353	7.534	1.388
7	0.370	2.915	0.363	7.601	1.401
8	0.380	2.943	0.373	7.659	1.414
9	0.390	2.969	0.383	7.726	1.427
10	0.400	2.994	0.393	7.793	1.439
11	0.360	2.876	0.353	7.595	1.382
12	0.370	2.898	0.363	7.693	1.393
13	0.380	2.925	0.373	7.756	1.406
14	0.390	2.950	0.383	7.828	1.418
15	0.400	2.976	0.393	7.889	1.430
16	0.360	2.917	0.353	7.380	1.402
17	0.370	2.946	0.363	7.438	1.416
18	0.380	2.972	0.373	7.509	1.428
19	0.390	3.002	0.383	7.552	1.443

TEST NO. 11

Date: 29 March 1954

Temperature of Water: 66.8°F.

Purpose of Test: Determination of the optimum angle of attack for the 1.0 inch stern hydrofoil with $l = 0.20$ ft. F.A.P., and $h = 1.0$ inch submergence, for all runs. Sandstrips on bow. Support device at stern.

Details and Location of Each Plot:

Runs 1-4, for $\alpha = -6.36^\circ$, curve 29

Runs 5-8, for $\alpha = 0^\circ$, curve 30

Runs 9-12, for $\alpha = 2^\circ$, curve 31

Runs 13-16 for $\alpha = 4^\circ$, curve 32

Each of the Above Curves will be found in Figure XII.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.360	2.889	0.353	7.527	1.388
2	0.370	2.917	0.363	7.590	1.402
3	0.390	2.962	0.383	7.763	1.423
4	0.400	2.993	0.393	7.798	1.438
5	0.360	2.902	0.353	7.458	1.395
6	0.370	2.930	0.363	7.522	1.408
7	0.390	2.980	0.383	7.668	1.432
8	0.400	3.012	0.393	7.697	1.447
9	0.360	2.878	0.353	7.586	1.383
10	0.370	2.898	0.363	7.693	1.393
11	0.390	2.950	0.383	7.828	1.418
12	0.400	2.980	0.393	7.869	1.432
13	0.360	2.835	0.353	7.817	1.362
14	0.370	2.864	0.363	7.886	1.376
15	0.390	2.917	0.383	8.010	1.402
16	0.400	2.940	0.393	8.088	1.413

TEST NO. 12

Date: 2 April 1954

Temperature of Water: 66.5°F.

- Purpose of Test: A. Runs 1-5, Re-evaluation of C_T versus $V/\sqrt{L}$ at 32 knot range of model with sandstrips and hydrofoil support device only. The hydrofoil support device is at 0.20 ft. F.A.P.
- B. Runs 6-10, Re-evaluation of C_T versus $V/\sqrt{L}$ of model with sandstrips only, at 32 knot range.
- C. Runs 11-18, Evaluation of varying the depth of submergence of the 1.0 inch stern hydrofoil. Sandstrips on bow. Support device at stern.

Details and Location of Each Plot:

Runs 1-5, curve 33, Figure XI.

Runs 6-10, curve 34, Figure IX.

Runs 11-14, 1 inch foil at $l = 0.20$ ft. F.A.P., $\alpha = -3.18^\circ$, $h =$ keel depth. Curve 35, Figure XXII.Runs 15-18, 1 inch foil at $l = 0.20$ ft. F.A.P., $\alpha = -3.18^\circ$, $h = 1.0$ inch below water line,

i.e., one chord length. Curve 36, Figure XXII.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.400	3.110	0.393	7.215	1.494
2	0.330	2.904	0.323	6.811	1.396
3	0.320	2.875	0.313	6.735	1.382
4	0.340	2.927	0.333	6.908	1.407
5	0.350	2.956	0.343	6.967	1.421
6	0.300	2.851	0.293	6.410	1.370
7	0.310	2.881	0.303	6.492	1.384
8	0.320	2.906	0.313	6.590	1.396
9	0.330	2.936	0.323	6.658	1.411
10	0.350	2.992	0.343	6.803	1.438
11	0.350	2.864	0.343	7.440	1.376
12	0.370	2.918	0.363	7.581	1.402
13	0.380	2.940	0.373	7.671	1.413
14	0.390	2.953	0.383	7.809	1.419
15	0.350	2.881	0.343	7.352	1.384
16	0.370	2.942	0.363	7.455	1.414
17	0.380	2.967	0.373	7.532	1.426
18	0.390	2.992	0.383	7.600	1.438

DATE: 10/10/1954
 LOCATION: 1/2 mile S. of
 Highway 100, near

1. The top of the section is a
 thin bed of sandstone, 1/2
 inch thick, containing small
 pebbles of quartz and
 feldspar. The sandstone is
 light gray and is
 well sorted. The pebbles
 are 1/4 to 1/2 inch in
 diameter. The sandstone
 is 1/2 inch thick and
 is well sorted. The
 pebbles are 1/4 to 1/2
 inch in diameter. The
 sandstone is 1/2 inch
 thick and is well sorted.
 The pebbles are 1/4 to
 1/2 inch in diameter.

Details and location of each
 bed in the section are
 given in the following
 table. The beds are
 numbered 1 to 10, from
 top to bottom. The
 thickness of each bed
 is given in feet. The
 color of each bed is
 given in the column
 headed "Color". The
 texture of each bed
 is given in the column
 headed "Texture". The
 fossil content of each
 bed is given in the
 column headed "Fossils".

Bed No.	Thickness (ft.)	Color	Texture	Fossils
1	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
2	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
3	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
4	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
5	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
6	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
7	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
8	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
9	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar
10	0.1	Light gray	Well sorted	Small pebbles of quartz and feldspar

TEST NO. 13

Date: 5 April 1954

Temperature of Water: 67°F.

Purpose of Test: Completion of evaluation of varying the depth of submergence of the 1.0 inch stern hydrofoil. Sandstrips on bow. Support device at stern.

Details and Location of Plot: Runs 1-6, 1.0 inch foil at $l = 0.20$ ft. F.A.P., $\alpha = -3.18^\circ$, $h = 0.687$ inch below water line. Curve 37, Figure XXII.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 79°F.	$V/\sqrt{L}$
1	0.350	2.884	0.343	7.342	1.386
2	0.370	2.937	0.363	7.486	1.411
3	0.380	2.963	0.373	7.556	1.424
4	0.390	2.993	0.383	7.602	1.438
5	0.360	2.907	0.353	7.434	1.397
6	0.340	2.850	0.333	7.299	1.370

TEST NO. 14

Date: 10 April 1954

Temperature of Water: 68.5°F.

- Purpose of Test:
- A. Runs 1-5, Re-evaluation of C_T versus $V/\sqrt{L}$ at the 15 knot range for the sanded model. No hydrofoils or hydrofoil support device are attached to the model.
 - B. Runs 6-10, Re-evaluation of C_T versus $V/\sqrt{L}$ at the 15 knot range for the sanded model, with stern hydrofoil support device attached at $l = 0.20$ ft. F.A.P. No hydrofoils attached.
 - C. Runs 11-15, Evaluation of C_T versus $V/\sqrt{L}$ at the 15 knot range for the 1.0 inch stern hydrofoil located at its optimum position, i.e., $l = 0.20$ ft. F.A.P., $h = 1$ inch submergence and $\alpha = -3.18^\circ$.
 - D. Runs 16-35, Determination of the optimum angle of attack for the 2.0 inch stern hydrofoil with $l = 0.05$ ft. A.A.P., and $h =$ keel depth, for all runs. Sandstrips on bow, support device at stern.
 - E. Runs 36-39, Evaluation of C_T versus $V/\sqrt{L}$ at the 32 knot range for the 3.0 inch stern hydrofoil located at its optimum position, i.e., $l = 0.175$ ft. A.A.P., $\alpha = 3^\circ$ and $h =$ keel depth, for all runs. Sandstrips on bow, support device at stern.
 - F. Runs 40-44, Evaluation of C_T versus $V/\sqrt{L}$ at the 15 knot range for the 3.0 inch stern hydrofoil located at its optimum position, i.e., $l = 0.175$ ft. A.A.P., $\alpha = 3^\circ$, and $h =$ keel depth, for all runs. Sandstrips on bow, support device at stern.

Date: 10/10/1954
 Department of State

100-100000

Subject: [illegible]

Reference: [illegible]

1. [illegible]

2. [illegible]

3. [illegible]

4. [illegible]

5. [illegible]

6. [illegible]

7. [illegible]

8. [illegible]

9. [illegible]

10. [illegible]

11. [illegible]

12. [illegible]

13. [illegible]

14. [illegible]

15. [illegible]

16. [illegible]

17. [illegible]

18. [illegible]

19. [illegible]

20. [illegible]

TEST NO. 14 (continued)

Date: 10 April 1954

Purpose of Test: G. Runs 45-49, Evaluation of C_T versus $V/\sqrt{L}$ at the 32 knot range for the 3.5 inch stern hydrofoil located at its optimum position, i.e., $l = 0.125$ ft. A.A.P., $\alpha = 1^\circ$, $h =$ keel depth.

Details and Location of Each Plot:

Runs 1-5, curve 38, Figure IX.
Runs 6-10, curve 39, Figure X.
Runs 11-15, curve 40, Figure XXI.
Runs 16-19, $\alpha = 0^\circ$, curve 41, Figure XIV.
Runs 20-23, $\alpha = 2^\circ$, curve 42, Figure XIV.
Runs 24-27, $\alpha = 5^\circ$, curve 43, Figure XIV.
Runs 28-31, $\alpha = -1.18^\circ$, curve 44, Figure XIV.
Runs 32-35, $\alpha = -3.18^\circ$, curve 45, Figure XIV.
Runs 36-39, curve 46, Figure XIX.
Runs 40-44, curve 47, Figure XXI.
Runs 45-49, curve 48, Figure XIX.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at $70^\circ F.$	$V/\sqrt{L}$
1	0.070	1.316	0.065	6.693	0.632
2	0.075	1.333	0.070	7.015	0.641
3	0.080	1.440	0.075	6.430	0.692
4	0.074	1.373	0.069	6.518	0.660
5	0.078	1.429	0.073	6.355	0.687
6	0.078	1.394	0.073	6.691	0.670
7	0.080	1.421	0.075	6.614	0.683
8	0.075	1.365	0.070	6.691	0.656
9	0.074	1.350	0.069	6.745	0.649
10	0.070	1.301	0.065	6.847	0.625
11	0.080	1.310	0.075	7.795	0.630
12	0.085	1.365	0.080	7.649	0.656
13	0.090	1.418	0.085	7.529	0.681
14	0.095	1.472	0.090	7.390	0.707
15	0.088	1.401	0.083	7.531	0.673

(continued)

Table 1. (continued)

Notes: 1. The figures in this table are based on the 1947-48 survey of the population of the United States, and are not necessarily comparable with the figures in the 1946-47 survey. 2. The figures in this table are based on the 1947-48 survey of the population of the United States, and are not necessarily comparable with the figures in the 1946-47 survey. 3. The figures in this table are based on the 1947-48 survey of the population of the United States, and are not necessarily comparable with the figures in the 1946-47 survey.

Table 1. (continued)

Notes: 1. The figures in this table are based on the 1947-48 survey of the population of the United States, and are not necessarily comparable with the figures in the 1946-47 survey. 2. The figures in this table are based on the 1947-48 survey of the population of the United States, and are not necessarily comparable with the figures in the 1946-47 survey. 3. The figures in this table are based on the 1947-48 survey of the population of the United States, and are not necessarily comparable with the figures in the 1946-47 survey.

Age	Sex	White	Black	Hispanic	Total
15-19	M	1,000,000	500,000	100,000	1,600,000
15-19	F	1,000,000	500,000	100,000	1,600,000
20-24	M	1,000,000	500,000	100,000	1,600,000
20-24	F	1,000,000	500,000	100,000	1,600,000
25-29	M	1,000,000	500,000	100,000	1,600,000
25-29	F	1,000,000	500,000	100,000	1,600,000
30-34	M	1,000,000	500,000	100,000	1,600,000
30-34	F	1,000,000	500,000	100,000	1,600,000
35-39	M	1,000,000	500,000	100,000	1,600,000
35-39	F	1,000,000	500,000	100,000	1,600,000
40-44	M	1,000,000	500,000	100,000	1,600,000
40-44	F	1,000,000	500,000	100,000	1,600,000
45-49	M	1,000,000	500,000	100,000	1,600,000
45-49	F	1,000,000	500,000	100,000	1,600,000
50-54	M	1,000,000	500,000	100,000	1,600,000
50-54	F	1,000,000	500,000	100,000	1,600,000
55-59	M	1,000,000	500,000	100,000	1,600,000
55-59	F	1,000,000	500,000	100,000	1,600,000
60-64	M	1,000,000	500,000	100,000	1,600,000
60-64	F	1,000,000	500,000	100,000	1,600,000
65-69	M	1,000,000	500,000	100,000	1,600,000
65-69	F	1,000,000	500,000	100,000	1,600,000
70-74	M	1,000,000	500,000	100,000	1,600,000
70-74	F	1,000,000	500,000	100,000	1,600,000
75-79	M	1,000,000	500,000	100,000	1,600,000
75-79	F	1,000,000	500,000	100,000	1,600,000
80-84	M	1,000,000	500,000	100,000	1,600,000
80-84	F	1,000,000	500,000	100,000	1,600,000
85-89	M	1,000,000	500,000	100,000	1,600,000
85-89	F	1,000,000	500,000	100,000	1,600,000
90-94	M	1,000,000	500,000	100,000	1,600,000
90-94	F	1,000,000	500,000	100,000	1,600,000
95-99	M	1,000,000	500,000	100,000	1,600,000
95-99	F	1,000,000	500,000	100,000	1,600,000
100+	M	1,000,000	500,000	100,000	1,600,000
100+	F	1,000,000	500,000	100,000	1,600,000

(continued)

TEST NO. 14 (continued)

Date: 10 April 1954

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70%	
				V/ $\sqrt{L}$	
16	0.370	2.958	0.363	7.392	1.421
17	0.380	2.983	0.373	7.469	1.434
18	0.360	2.928	0.353	7.338	1.407
19	0.350	2.896	0.343	7.294	1.392
20	0.350	2.875	0.343	7.403	1.382
21	0.360	2.903	0.353	7.470	1.395
22	0.370	2.931	0.363	7.531	1.408
23	0.380	2.963	0.373	7.571	1.424
24	0.350	2.835	0.343	7.613	1.362
25	0.360	2.863	0.353	7.623	1.376
26	0.370	2.893	0.363	7.736	1.390
27	0.380	2.920	0.373	7.798	1.403
28	0.350	2.899	0.343	7.278	1.393
29	0.360	2.928	0.353	7.338	1.407
30	0.370	2.960	0.363	7.382	1.422
31	0.380	2.990	0.373	7.432	1.437
32	0.350	2.891	0.343	7.319	1.389
33	0.360	2.920	0.353	7.380	1.403
34	0.370	2.950	0.363	7.433	1.418
35	0.380	2.982	0.373	7.473	1.433
36	0.350	2.812	0.343	7.740	1.351
37	0.360	2.840	0.353	7.805	1.365
38	0.390	2.923	0.383	7.990	1.405
39	0.410	2.975	0.403	8.115	1.430
40	0.115	1.479	0.110	8.954	0.711
41	0.110	1.429	0.105	9.153	0.687
42	0.113	1.456	0.108	9.037	0.700
43	0.118	1.508	0.112	8.810	0.725
44	0.108	1.404	0.103	9.275	0.675
45	0.380	2.957	0.373	7.600	1.421
46	0.380	2.893	0.353	7.523	1.390
47	0.370	2.923	0.363	7.572	1.405
48	0.390	2.981	0.383	7.681	1.432
49	0.340	2.835	0.333	7.388	1.362

Year	Area	Population	Area	Population	Area	Population
1991	100.0	100.0	100.0	100.0	100.0	100.0
1992	100.0	100.0	100.0	100.0	100.0	100.0
1993	100.0	100.0	100.0	100.0	100.0	100.0
1994	100.0	100.0	100.0	100.0	100.0	100.0
1995	100.0	100.0	100.0	100.0	100.0	100.0
1996	100.0	100.0	100.0	100.0	100.0	100.0
1997	100.0	100.0	100.0	100.0	100.0	100.0
1998	100.0	100.0	100.0	100.0	100.0	100.0
1999	100.0	100.0	100.0	100.0	100.0	100.0
2000	100.0	100.0	100.0	100.0	100.0	100.0
2001	100.0	100.0	100.0	100.0	100.0	100.0
2002	100.0	100.0	100.0	100.0	100.0	100.0
2003	100.0	100.0	100.0	100.0	100.0	100.0
2004	100.0	100.0	100.0	100.0	100.0	100.0
2005	100.0	100.0	100.0	100.0	100.0	100.0
2006	100.0	100.0	100.0	100.0	100.0	100.0
2007	100.0	100.0	100.0	100.0	100.0	100.0
2008	100.0	100.0	100.0	100.0	100.0	100.0
2009	100.0	100.0	100.0	100.0	100.0	100.0
2010	100.0	100.0	100.0	100.0	100.0	100.0
2011	100.0	100.0	100.0	100.0	100.0	100.0
2012	100.0	100.0	100.0	100.0	100.0	100.0
2013	100.0	100.0	100.0	100.0	100.0	100.0
2014	100.0	100.0	100.0	100.0	100.0	100.0
2015	100.0	100.0	100.0	100.0	100.0	100.0
2016	100.0	100.0	100.0	100.0	100.0	100.0
2017	100.0	100.0	100.0	100.0	100.0	100.0
2018	100.0	100.0	100.0	100.0	100.0	100.0
2019	100.0	100.0	100.0	100.0	100.0	100.0
2020	100.0	100.0	100.0	100.0	100.0	100.0

TEST NO. 15

Dates: 11 April 1954

Temperature of Water: 68.5°F.

- Purpose of Test:
- A. Runs 1-16, Determination of optimum longitudinal position for the 2.0 inch bow hydrofoil with $\alpha = 0^\circ$ and $h =$ keel depth, for all runs. Sandstrips on bow. Support device at bow.
 - B. Runs 17-32, Determination of the optimum angle of attack for the 2.0 inch bow hydrofoil with $l = 0.15$ ft. F.F.P., $h =$ keel depth, for all runs. Sandstrips on bow. Support device at bow.
 - C. Runs 33-36, Evaluation of C_T versus V/L at the 32 knot range for the sanded model, with the bow hydrofoil support device attached at $l = 0.15$ ft. F.F.P. No hydrofoils attached.

Details and Location of Each Plot:

Runs 1-4, $l = 0.20$ ft. F.F.P., curve 49.
Runs 5-8, $l = 0.30$ ft. F.F.P., curve 50.
Runs 9-12, $l = 0.10$ ft. F.F.P., curve 51.
Runs 13-16, $l =$ at F.P., curve 52.
Runs 17-20, $\alpha = -3.18^\circ$, curve 53.
Runs 21-24, $\alpha = -1.18^\circ$, curve 54.
Runs 25-28, $\alpha = 1^\circ$, curve 55.
Runs 29-32, $\alpha = 3^\circ$, curve 56.

All of the above curves will be found in Figure XXIII.
Runs 33-36, curve 57, Figure XI.

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
1	0.340	2.828	0.333	7.426	1.359
2	0.360	2.888	0.353	7.549	1.388
3	0.380	2.950	0.373	7.639	1.418
4	0.400	3.012	0.393	7.717	1.447
5	0.340	2.812	0.333	7.515	1.351

(continued)

UNIT 22
 1. The first part of the unit is a short story.

2. The second part of the unit is a short story.
 3. The third part of the unit is a short story.
 4. The fourth part of the unit is a short story.
 5. The fifth part of the unit is a short story.

6. The sixth part of the unit is a short story.
 7. The seventh part of the unit is a short story.
 8. The eighth part of the unit is a short story.
 9. The ninth part of the unit is a short story.
 10. The tenth part of the unit is a short story.

11. The eleventh part of the unit is a short story.
 12. The twelfth part of the unit is a short story.
 13. The thirteenth part of the unit is a short story.
 14. The fourteenth part of the unit is a short story.
 15. The fifteenth part of the unit is a short story.

UNIT 22

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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All of the above are short stories.

Unit	Page	Topic	Author	Year	Genre	Length	Rating	Notes
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10
11	11	11	11	11	11	11	11	11
12	12	12	12	12	12	12	12	12
13	13	13	13	13	13	13	13	13
14	14	14	14	14	14	14	14	14
15	15	15	15	15	15	15	15	15
16	16	16	16	16	16	16	16	16
17	17	17	17	17	17	17	17	17
18	18	18	18	18	18	18	18	18
19	19	19	19	19	19	19	19	19
20	20	20	20	20	20	20	20	20
21	21	21	21	21	21	21	21	21
22	22	22	22	22	22	22	22	22
23	23	23	23	23	23	23	23	23
24	24	24	24	24	24	24	24	24
25	25	25	25	25	25	25	25	25
26	26	26	26	26	26	26	26	26
27	27	27	27	27	27	27	27	27
28	28	28	28	28	28	28	28	28
29	29	29	29	29	29	29	29	29
30	30	30	30	30	30	30	30	30
31	31	31	31	31	31	31	31	31
32	32	32	32	32	32	32	32	32
33	33	33	33	33	33	33	33	33
34	34	34	34	34	34	34	34	34
35	35	35	35	35	35	35	35	35
36	36	36	36	36	36	36	36	36
37	37	37	37	37	37	37	37	37
38	38	38	38	38	38	38	38	38
39	39	39	39	39	39	39	39	39
40	40	40	40	40	40	40	40	40
41	41	41	41	41	41	41	41	41
42	42	42	42	42	42	42	42	42
43	43	43	43	43	43	43	43	43
44	44	44	44	44	44	44	44	44
45	45	45	45	45	45	45	45	45
46	46	46	46	46	46	46	46	46
47	47	47	47	47	47	47	47	47
48	48	48	48	48	48	48	48	48
49	49	49	49	49	49	49	49	49
50	50	50	50	50	50	50	50	50
51	51	51	51	51	51	51	51	51
52	52	52	52	52	52	52	52	52
53	53	53	53	53	53	53	53	53
54	54	54	54	54	54	54	54	54
55	55	55	55	55	55	55	55	55
56	56	56	56	56	56	56	56	56
57	57	57	57	57	57	57	57	57
58	58	58	58	58	58	58	58	58
59	59	59	59	59	59	59	59	59
60	60	60	60	60	60	60	60	60
61	61	61	61	61	61	61	61	61
62	62	62	62	62	62	62	62	62
63	63	63	63	63	63	63	63	63
64	64	64	64	64	64	64	64	64
65	65	65	65	65	65	65	65	65
66	66	66	66	66	66	66	66	66
67	67	67	67	67	67	67	67	67
68	68	68	68	68	68	68	68	68
69	69	69	69	69	69	69	69	69
70	70	70	70	70	70	70	70	70
71	71	71	71	71	71	71	71	71
72	72	72	72	72	72	72	72	72
73	73	73	73	73	73	73	73	73
74	74	74	74	74	74	74	74	74
75	75	75	75	75	75	75	75	75
76	76	76	76	76	76	76	76	76
77	77	77	77	77	77	77	77	77
78	78	78	78	78	78	78	78	78
79	79	79	79	79	79	79	79	79
80	80	80	80	80	80	80	80	80
81	81	81	81	81	81	81	81	81
82	82	82	82	82	82	82	82	82
83	83	83	83	83	83	83	83	83
84	84	84	84	84	84	84	84	84
85	85	85	85	85	85	85	85	85
86	86	86	86	86	86	86	86	86
87	87	87	87	87	87	87	87	87
88	88	88	88	88	88	88	88	88
89	89	89	89	89	89	89	89	89
90	90	90	90	90	90	90	90	90
91	91	91	91	91	91	91	91	91
92	92	92	92	92	92	92	92	92
93	93	93	93	93	93	93	93	93
94	94	94	94	94	94	94	94	94
95	95	95	95	95	95	95	95	95
96	96	96	96	96	96	96	96	96
97	97	97	97	97	97	97	97	97
98	98	98	98	98	98	98	98	98
99	99	99	99	99	99	99	99	99
100	100	100	100	100	100	100	100	100

TEST NO. 15 (continued)

Dates 11 April 1954

Run No.	Applied Force (lbs.)	Speed (knots)	Total Resistance (lbs.)	$C_T \times 10^3$ at 70°F.	$V/\sqrt{L}$
6	0.360	2.875	0.353	7.616	1.382
7	0.380	2.937	0.373	7.706	1.411
8	0.400	2.998	0.393	7.789	1.441
9	0.340	2.824	0.333	7.447	1.357
10	0.360	2.888	0.353	7.549	1.388
11	0.380	2.945	0.373	7.664	1.415
12	0.400	3.003	0.393	7.763	1.443
13	0.340	2.720	0.333	8.032	1.307
14	0.360	2.776	0.353	8.172	1.334
15	0.380	2.828	0.373	8.318	1.359
16	0.400	2.882	0.393	8.440	1.385
17	0.340	2.805	0.333	7.551	1.348
18	0.360	2.865	0.353	7.669	1.377
19	0.380	2.920	0.373	7.800	1.403
20	0.400	2.977	0.393	7.903	1.431
21	0.340	2.827	0.333	7.430	1.358
22	0.360	2.889	0.353	7.542	1.388
23	0.380	2.952	0.373	7.628	1.418
24	0.400	3.011	0.393	7.723	1.447
25	0.340	2.808	0.333	7.535	1.349
26	0.360	2.871	0.353	7.638	1.380
27	0.380	2.930	0.373	7.743	1.408
28	0.400	2.991	0.393	7.826	1.437
29	0.340	2.744	0.333	7.889	1.319
30	0.360	2.802	0.353	8.023	1.346
31	0.380	2.865	0.373	8.104	1.377
32	0.400	2.923	0.393	8.201	1.405
33	0.320	2.877	0.313	6.743	1.382
34	0.340	2.932	0.333	6.902	1.409
35	0.360	2.995	0.353	7.008	1.439
36	0.350	2.965	0.343	6.952	1.425

Year	1971	1972	1973	1974	1975
1971	100.0	100.0	100.0	100.0	100.0
1972	100.0	100.0	100.0	100.0	100.0
1973	100.0	100.0	100.0	100.0	100.0
1974	100.0	100.0	100.0	100.0	100.0
1975	100.0	100.0	100.0	100.0	100.0
1976	100.0	100.0	100.0	100.0	100.0
1977	100.0	100.0	100.0	100.0	100.0
1978	100.0	100.0	100.0	100.0	100.0
1979	100.0	100.0	100.0	100.0	100.0
1980	100.0	100.0	100.0	100.0	100.0
1981	100.0	100.0	100.0	100.0	100.0
1982	100.0	100.0	100.0	100.0	100.0
1983	100.0	100.0	100.0	100.0	100.0
1984	100.0	100.0	100.0	100.0	100.0
1985	100.0	100.0	100.0	100.0	100.0
1986	100.0	100.0	100.0	100.0	100.0
1987	100.0	100.0	100.0	100.0	100.0
1988	100.0	100.0	100.0	100.0	100.0
1989	100.0	100.0	100.0	100.0	100.0
1990	100.0	100.0	100.0	100.0	100.0
1991	100.0	100.0	100.0	100.0	100.0
1992	100.0	100.0	100.0	100.0	100.0
1993	100.0	100.0	100.0	100.0	100.0
1994	100.0	100.0	100.0	100.0	100.0
1995	100.0	100.0	100.0	100.0	100.0
1996	100.0	100.0	100.0	100.0	100.0
1997	100.0	100.0	100.0	100.0	100.0
1998	100.0	100.0	100.0	100.0	100.0
1999	100.0	100.0	100.0	100.0	100.0
2000	100.0	100.0	100.0	100.0	100.0
2001	100.0	100.0	100.0	100.0	100.0
2002	100.0	100.0	100.0	100.0	100.0
2003	100.0	100.0	100.0	100.0	100.0
2004	100.0	100.0	100.0	100.0	100.0
2005	100.0	100.0	100.0	100.0	100.0
2006	100.0	100.0	100.0	100.0	100.0
2007	100.0	100.0	100.0	100.0	100.0
2008	100.0	100.0	100.0	100.0	100.0
2009	100.0	100.0	100.0	100.0	100.0
2010	100.0	100.0	100.0	100.0	100.0
2011	100.0	100.0	100.0	100.0	100.0
2012	100.0	100.0	100.0	100.0	100.0
2013	100.0	100.0	100.0	100.0	100.0
2014	100.0	100.0	100.0	100.0	100.0
2015	100.0	100.0	100.0	100.0	100.0
2016	100.0	100.0	100.0	100.0	100.0
2017	100.0	100.0	100.0	100.0	100.0
2018	100.0	100.0	100.0	100.0	100.0
2019	100.0	100.0	100.0	100.0	100.0
2020	100.0	100.0	100.0	100.0	100.0
2021	100.0	100.0	100.0	100.0	100.0
2022	100.0	100.0	100.0	100.0	100.0
2023	100.0	100.0	100.0	100.0	100.0
2024	100.0	100.0	100.0	100.0	100.0
2025	100.0	100.0	100.0	100.0	100.0

APPENDIX E

Sample Calculations

APPENDIX E

Sample Calculations

Model DTMB-DD 332

Consider Run 1 of Test 1, conducted on 12 Feb. 1954:

Model Length, $L = 4.333$ ft.

Wetted Surface, $S = 2.028$ sq.ft.

Water Temperature $= 66^{\circ}\text{F.}$

Fresh Water Density, $\rho = 1.9371$ slugs/ft.³

Fresh Water Kinematic Viscosity, $\nu = 1.1133 \times 10^{-5}$
ft.²/sec.

Applied Force 0.0100 lbs.

Speed 0.615 knots or 1.038 ft./sec.

*Pulley Friction Corresponding to Speed 0.0041 lbs.

* The pulley friction is read from a calibration chart at the M.I.T. Towing Tank. It is the friction arising from the 5 lb. static tension in the towing cable.

1) Calculation of model total resistance coefficient at testing temperature

Force acting on the model = (Applied Force) - (Pulley Friction)

$$R_T = 0.0100 - 0.0041 = 0.0059 \text{ lb.}$$

$$C = \frac{R_{Tm}}{\frac{1}{2} \rho U^2} = \frac{0.0059}{\frac{1}{2} (1.9371) (2.028) (1.038)^2} = 2.786 \times 10^{-3} \text{ at } 66^{\circ}\text{F.}$$

APPENDIX E

EXPERIMENTAL DATA

Model 100-100 100

Considered run I of Test 1, conducted on 12 Feb. 1954

Model 100-100 100

Rated power, $P = 0.002$ hp

Rated temperature = 100°

From water density, $\rho = 1.94$ slug/ft³

From water kinematic viscosity, $\nu = 1.13 \times 10^{-5}$ ft²/sec

Rated force 0.0100 lb

Rated speed 0.111 in/sec

Model 100-100 100

The only test run is run 1, which is a calibration run. It is the only run for which the static pressure is the only data.

1) Calculation of model total resistance

Force acting on the model = (dynamic pressure) (area)

$$F = 0.002 - 0.001 = 0.001 \text{ lb}$$

$$C_D = \frac{F}{\frac{\rho V^2}{2} A} = \frac{0.001}{\frac{1.94 (0.111)^2}{2} (0.002)} = 1.13 \times 10^{-5}$$

2) Correction of model total resistance coefficient to standard temperature of 70°F.

$$\text{Reynold's number at test temperature} = \frac{VL}{\nu} = \frac{1.038 \times 4.333}{1.1133 \times 10^{-5}} \\ = 4.042 \times 10^5$$

$$\text{Reynold's number at } 70^\circ\text{F.} = \frac{VL}{\nu} = \frac{1.038 \times 4.333}{1.0552 \times 10^{-5}} \\ = 4.265 \times 10^5$$

Using Schoenherr's formulation for frictional resistance coefficient as tabulated for varying Reynold's number in reference (12), we obtain:

$$\text{at } R_e = 4.042 \times 10^5, \quad C_{F_m} = 5.283 \times 10^{-3}$$

$$\text{at } R_e = 4.265 \times 10^5, \quad C_{F_m} = 5.225 \times 10^{-3}$$

$$\text{Correction to } C_T = (5.225 - 5.283) \times 10^{-3} = (-) 0.058 \times 10^{-3}$$

Finally, at 70°F:

$$C_T = (2.786 \times 10^{-3}) - (0.058 \times 10^{-3}) = 2.728 \times 10^{-3}$$

3) Speed length ratio for run

$$\text{Speed length ratio} = \frac{V}{\sqrt{L}} = \frac{0.615}{\sqrt{4.333}} = 0.296$$

Collection of small, dark, irregularly shaped, brownish, granular, and somewhat lustrous particles of size 0.1 to 0.5 mm.

Reynolds' number at 100°C = $\frac{V}{\nu} = \frac{1.0 \times 10^{-2}}{1.0 \times 10^{-6}} = 10^4$

$$Re = 10^4 = 10^4$$

Reynolds' number at 100°C = $\frac{V}{\nu} = \frac{1.0 \times 10^{-2}}{1.0 \times 10^{-6}} = 10^4$

$$Re = 10^4 = 10^4$$

Using experimental correlation for turbulent flow, the friction coefficient is calculated for various Reynolds numbers in reference (1), we obtain

$$f = 0.0045 = 4.5 \times 10^{-3} \quad \text{for } Re = 10^4$$

$$f = 0.0045 = 4.5 \times 10^{-3} \quad \text{for } Re = 10^4$$

$$\text{Conversion to } C_T = (0.0045 - 0.0045) \times 10^{-3} = (-) 0.00 \times 10^{-3}$$

Finally, at 100°C:

$$C_T = (0.0045 \times 10^{-3}) - (0.0045 \times 10^{-3}) = 0.00 \times 10^{-3}$$

3) Speed length ratio for the

$$\text{Speed length ratio} = \frac{V}{L} = \frac{0.01}{1.0} = 0.01$$

4) Discussion of wetted surface used in Calculations

Throughout the calculations the value of wetted surface used was always that of the model only, not the model plus that of any attached hydrofoil. As a result, the values of C_T obtained are all higher than would have been the case if the added wetted surface of the foils had been included.

This action is justified on these grounds. The foil is not normally considered part of the model. Hence, if the calculations show that a value of C_T is obtained which is less than the value of C_T without the foil, it is a positive indication that the reduction was due entirely to the hydrofoil. The attempt, therefore, is to keep model and hydrofoil separate and distinct in the calculations so as to be able to point toward any improvement as being due solely to the added presence of the hydrofoil. There is, accordingly, a common basis for direct comparison of total resistance coefficient with and without hydrofoils. In reference (5) will be found additional discussion of this point.

APPENDIX F

Expected Increase in C_T at 32 Knot Range Due
to Hydrofoil Wetted Surface

Abstract

The purpose of this study was to determine the effect of a 12-week training program on the physical fitness of sedentary individuals. The study was conducted over a 12-week period, with participants undergoing a series of physical fitness tests at the beginning and end of the program. The results of the study are presented in the following table.

Table 1

The following table shows the results of the physical fitness tests conducted at the beginning and end of the 12-week training program. The tests included a 1-mile run, a 1-mile walk, a 1-mile swim, and a 1-mile bike ride. The results are presented in the following table.

Test	Beginning	End
1-mile run	15:00	12:00
1-mile walk	20:00	18:00
1-mile swim	25:00	22:00
1-mile bike ride	30:00	28:00

The results of the study indicate that the 12-week training program had a significant positive effect on the physical fitness of sedentary individuals. The participants showed a decrease in time taken to complete each test, indicating an improvement in their physical fitness. The most significant improvement was seen in the 1-mile run, where the time decreased by 3 minutes. This suggests that the training program was effective in improving the participants' cardiovascular fitness.

APPENDIX F

Expected Increase in C_T at 32 Knot Range Due to Hydrofoil Wetted Surface

As was mentioned in Appendix E, Sample Calculations, the additional wetted surface of the hydrofoils was not added to that of the model when calculating the values of C_T for the various runs.

Now the results of the stern hydrofoil analysis indicate that none of the five hydrofoils resulted in a C_T at the 32 knot range which was lower than the value of C_T to be expected without the presence of hydrofoils. Accordingly, it is not possible to evaluate the wave reducing effects of the hydrofoils unless we first know what was the effect of the frictional resistance caused by the hydrofoil wetted surface.

The following calculations were therefore made to evaluate these added frictional resistance effects.

Discussion

As the results of the present study are in good agreement with the results of other workers, it is not necessary to discuss them in detail.

It was pointed out in the Introduction that the results of the present study are in good agreement with the results of other workers. It is not necessary to discuss them in detail.

The results of the present study are in good agreement with the results of other workers. It is not necessary to discuss them in detail.

The following table shows the results of the present study.

C_T of banded model (no stern foil support device)

at 32 knot range = 6.620×10^{-3}

Added Increment to C_T caused by stern foil support

device = 0.248×10^{-3}

Span of Foils = 5.330 inches

Model Wetted Surface = 2.025 sq. ft.

Foil Wetted Surface = (Span of Foil) x (Wetted Perimeter)

Percent Increase in Wetted Surface = $\frac{\text{Foil Wetted Surface}}{\text{Model Wetted Surface}} \times 100$

Expected C_T due to Added Wetted Surface

$$= (1 + \frac{\% \text{Increase}}{100}) (6.620 \times 10^{-3})$$

The figures in the far right column are plotted as dashes in Figure XX.

Chord Length (inches)	Wetted Perimeter (inches)	Foil Wetted Surface sq. in.	Foil Wetted Surface sq. ft.	Percent Increase in Wetted Surface	Expected C_T due to Added Wetted Surface	Expected C_T plus ΔC_T due to Support Device
1.0	2.01	10.71	0.0744	3.670	6.870×10^{-3}	7.118×10^{-3}
1.5	3.15	16.78	0.1164	5.735	6.990×10^{-3}	7.238×10^{-3}
2.0	4.22	22.84	0.1587	7.810	7.120×10^{-3}	7.378×10^{-3}
2.5	5.25	27.98	0.1942	9.570	7.240×10^{-3}	7.488×10^{-3}
3.0	6.27	33.45	0.2322	11.440	7.570×10^{-3}	7.818×10^{-3}

1. The first group is the group of the first 100 cases (100 cases in total).

2. The second group is the group of the next 100 cases (100 cases in total).

3. The third group is the group of the next 100 cases (100 cases in total).

4. The fourth group is the group of the next 100 cases (100 cases in total).

5. The fifth group is the group of the next 100 cases (100 cases in total).

6. The sixth group is the group of the next 100 cases (100 cases in total).

7. The seventh group is the group of the next 100 cases (100 cases in total).

$$= (1 + \frac{1}{100})^{100} \approx 2.718$$

The figure in the last column is the value of the function $f(x)$ at $x = 100$.

Group	Number of cases	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
1	100	1.00	0.00	1.00	0.00	1.00	0.00
2	100	1.01	0.01	1.01	0.01	1.01	0.01
3	100	1.02	0.02	1.02	0.02	1.02	0.02
4	100	1.03	0.03	1.03	0.03	1.03	0.03
5	100	1.04	0.04	1.04	0.04	1.04	0.04
6	100	1.05	0.05	1.05	0.05	1.05	0.05
7	100	1.06	0.06	1.06	0.06	1.06	0.06

APPENDIX G

Prediction of Optimum Longitudinal Position
for 2 inch Bow Hydrofoil at 2.920 Knots

ANNEX 2

TABLE 2.1: Summary of the results of the analysis of the data from the 1990-1991 survey.

Variable	Mean	Standard Deviation	Minimum	Maximum	Number of Observations
Age	35.2	12.5	18	65	1000
Gender	0.52	0.50	0	1	1000
Marital Status	0.78	0.41	0	1	1000
Education	12.5	2.5	8	16	1000
Income	15000	5000	5000	30000	1000
Health	0.85	0.35	0	1	1000

APPENDIX G

Prediction of Optimum Longitudinal Position for 2 inch Bow Hydrofoil at 2.920 Knots

By a series of observations of the transverse bow wave profile, it was established that the crest of the first bow wave occurred at a point 12.00 inches aft of the Forward Perpendicular. Now previous investigations on bow hydrofoils indicated that the hydrofoil should be located one quarter wave length forward of the first bow crest.

Following reference (2) the expressions for wave length are:

$$\lambda = 0.557 L \left(\frac{V}{L} \right)^2$$

$$\lambda = 0.557 V^2 = 0.557 (2.920 \times 1.689)^2$$

$$\lambda = 4.74 \text{ ft.}$$

Then $\frac{\lambda}{4} = \frac{4.74}{4} = 1.185 \text{ ft.} = 14.25 \text{ inches}$

Finally, recommended position of bow hydrofoil was found to be:

$$\text{Best Position} = 14.25 - 12.00 = 2.25 \text{ in. forward of the forward perpendicular.}$$

Examination of the following figures shows that the
 hypothesis is not correct.

By a series of observations at the following time
 were made. It was established that the rate of the
 first two were constant at a value of 1.000 and at
 the same time, the second two were constant at
 the same value. It was also established that the
 first two were constant at the same value. It was
 also established that the first two were constant
 at the same value. It was also established that
 the first two were constant at the same value.

Following equation (1) the hypothesis is not

correct.

$$K = 0.0001 \left(\frac{1}{1} \right) = 0.0001$$

$$K = 0.0001 \left(\frac{1}{1} \right) = 0.0001$$

$$K = 0.0001$$

$$K = 0.0001 \left(\frac{1}{1} \right) = 0.0001$$

It is seen that the hypothesis is not correct.

The following figures show that the hypothesis is not correct.

By experiment, the best position was established as being 1.80 inches forward of the Forward Perpendicular, therefore:

Error in Prediction = $2.25 - 1.80 = 0.45$ inch

Considering that visual observation was employed to establish the position of the first bow crest, this small error is quite acceptable in making a first approximation to the proper location.

of movement, the two parties are separated
in 1942 being followed by the second separation
in 1943.

There is separation = 1941 - 1942 = 0.44

Considered that several observations are made
in relation to the position of the line and the
well water is made separately in 1941 and 1942
separately in the same location.

It is possible that the separation is made in
1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

separation is made in 1941 and 1942, and the separation is made in 1941

APPENDIX H

Estimate of the Magnitude of Errors

1. The first part of the report concerns the
general situation of the country and the
state of the economy.

2. The second part of the report concerns the
state of the economy and the state of the
economy.

3. The third part of the report concerns the
state of the economy and the state of the
economy.

4. The fourth part of the report concerns the
state of the economy and the state of the
economy.

5. The fifth part of the report concerns the
state of the economy and the state of the
economy.

6. The sixth part of the report concerns the
state of the economy and the state of the
economy.

7. The seventh part of the report concerns the
state of the economy and the state of the
economy.

8. The eighth part of the report concerns the
state of the economy and the state of the
economy.

9. The ninth part of the report concerns the
state of the economy and the state of the
economy.

APPENDIX H

Estimate of the Magnitude of Errors

There were five experimentally controlled or measured variables in this thesis. They are listed below and for each is quoted an estimate of the possible error that may have occurred in their measurement:

Towing Force	± 0.0001 lb.
Towing Velocity	± 0.001 knot
Hydrofoil Longitudinal Position	± 0.002 ft.
Hydrofoil Angle of Attack	± 0.25 degree
Hydrofoil Depth of Submergence	± 0.002 ft.

The error introduced by the cracking of the model's bottom paint is not readily estimated in the manner shown above. This fact lessens the quantitative value of the results; however, the qualitative results suffer absolutely no depreciation because of this situation. The significant results of this thesis are qualitative in nature and accordingly their accuracy is a function of the thoroughness of experimental investigation. By thoroughness is meant a rigorous search into all the facets that influence the performance of a hydrofoil. It is on this basis that the thesis must be objectively viewed.



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